SCIENTIFIC AMERICAN SUPPLEMENT. No 1838

Entered at the Post Office of New York, N. Y., as Second Class Matter.
Copyright, 1910, by Munn & Co., Inc.

Published weekly by Munn & Co., Inc., at 361 Broadway, New York.

Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York.

Scientific American, established 1845.
Scientific American Supplement, Vol. LXXI., No. 1838.

NEW YORK, MARCH 25, 1911.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

An English Water Dynamometer for Absorbing 1,000 Brake Horse-power

By Frank C. Perkins.

The accompanying illustration shows the construction and method of operation of a 21-inch water dynamometer of the Froude type, now in service in a testing department of a shop at Worcester, England, and capable of absorbing 1,000 brake horse-power at 700 revolutions per minute.

This machine was designed for the purpose of determining with absolute accuracy the power developed by an engine or motor, in an expeditious and practical manner, and is capable of regulation so that the power put into it at any speed can be absorbed from the minimum to the maximum capacity of the dynamometer.

The dynamometer consists primarily of a turbine or rotator revolving within a casing which is mounted on friction rollers and connected to a water supply, so as to enable the casing to run full of water when the machine is in use. The rotor is fixed to the shaft which projects on either side of the casing, and to which the engine or motor to be tested is coupled. Engines or motors of either direction of rotation can thus be proved on the one machine.

Each disk face of the rotator is formed with a semi-elliptical annular channel divided into a number of compartments by means of oblique vanes. The corresponding faces of the casing are also formed with similar channels divided in the same way. The channels on the rotator and the casing thus form two complete annular channels of elliptical cross-section, each channel being divided, as previously stated, into compartments by means of the oblique vanes.

The water in each annular channel is rotated continuously by the centrifugal force imparted to it by the rotator, and it passes from one compartment into the next, and so on. An extremely high speed of rotation of the water is obtained, and the power or energy put into the dynamometer is by this means converted into heat which passes in the water leaving the machine.

The motion of the water causes the rotator to react on the casing and tends to turn it on the friction rollers. This is prevented by means of an extension or arm, working between stops at the end of which are the balance weights and the counterbalance by which is measured the actual power put into the dynamometer.

In order to reduce the power absorbed by the dynamometer when required, thin metallic shields are provided which are interposed between the faces of the rotator and the casing, thereby cutting off a portion of the effective area of the annular channels. In this manner the power may be reduced from the maximum down to about one-thirtieth of that amount.

The friction rollers supporting the casing are adjustable, so that the dynamometer shaft may be readily brought in line with that of the engine or motor under test.

The horse-power absorbed by the dynamometer = brake horse-power of engine or motor $= \dfrac{W \times N}{K}$

when

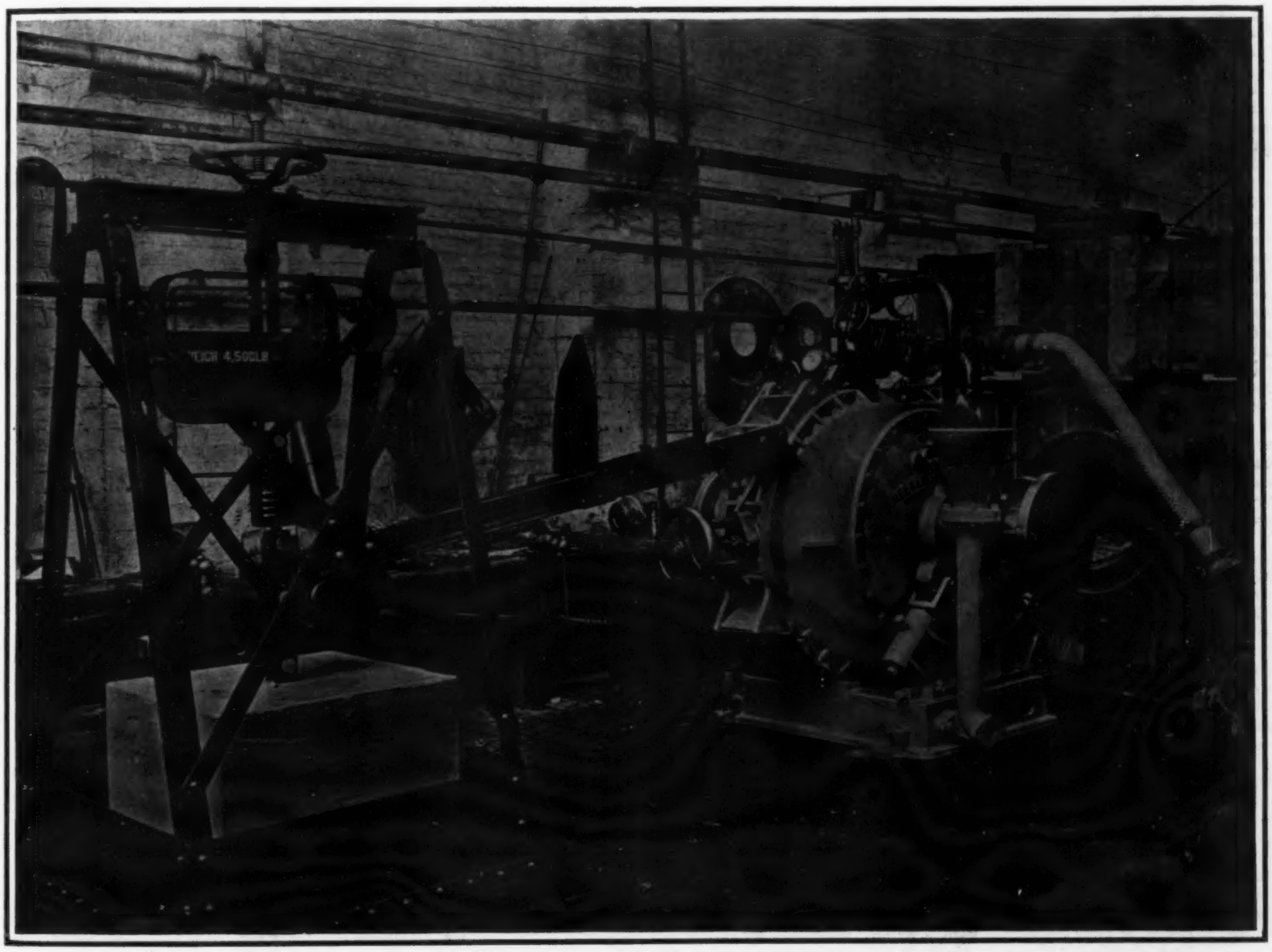
W = The effective weight in pounds at the end of the dynamometer arm.

N = Revolutions per minute.

K = The constant for each machine, and is derived from $\dfrac{33{,}000}{\pi \times 2L}$ as in the Prony brake formula, where L equals the radius or the length of the arm.

The quantity of water used = 1.89 gallons per horse-power per hour, as can be obtained from the following calculation:

$$\text{Gallons per hour} = \frac{\text{H. P.} \times 33{,}000 \times 60}{778 \times 10 \text{ Temp. difference between water at inlet and outlet.}}$$



21-INCH FROUDE WATER DYNAMOMETER AT WORCESTER, ENGLAND, CAPABLE OF ABSORBING 1,000 BRAKE HORSE-POWER AT 700 REVOLUTIONS PER MINUTE

Handling Passengers on a Rapid Transit Railroad*

Construction of a Rapid Transit Line as Illustrated by the Hudson and Manhattan Railroad

By J. Vipond Davies

PASSENGER transportation has developed the most complex problem which is to-day presented to the engineer for solution. The immense increase of population, particularly with reference to the concentration in cities, has produced new and grave conditions which have to be cared for by a careful study of individual cases, as each case requires absolutely new and independent treatment. With the steam railroads the problem of handling passenger traffic remains very much as it formerly did, except that with the extension of cities into their suburban districts the local traffic has become so much heavier that the distribution of passengers from the terminal destination introduces a new and serious problem. The number of persons who desire an all-the-year-round residence in the country districts, and who conduct business within the cities, is becoming yearly greater, and is only made possible by improved transit facilities being provided. This condition has also become a considerable factor in increasing the taxable values of suburban real estate and in developing real estate in the suburban districts of the great cities. London and New York offer the best illustrations of this condition, as in each of these cities there is a small district of limited area in which the bulk of the business is transacted, and a huge territory, radiating in every direction, where the business people have their residences. The state line between New York and New Jersey is a fictitious division; and, eliminating all consideration of the boundary-line between these two states, there is a district tributary to New York city which has a total population of over 6,500,000 persons. In a community of this character the nearer one gets to the center of the city the more dense becomes the traffic, the need for increased transit facilities greater, and the possibility of movement slower, all on account of the great concentration and the interference of cross-streams of travel. Every one is familiar with the fact that for reasonably short distances within this zone of density one can reach his destination quite as quickly by walking as by using a surface car. As one gets farther from the center of a large city and approaches the country, the traffic thins out, proportionally with the density of the population, and at the same time the possible speed of transportation becomes greater. The latest figures available indicate that the total movement of passenger traffic within the metropolitan district of New York aggregates very close to 2,000,000,000 passengers a year on all lines, which is equivalent to 308 rides per capita per annum, and the movement of passengers within the Borough of Manhattan averages over 400 rides per capita per annum. In order to get more rapid service for passenger traffic it has become necessary in New York to move the means of transportation from the surface of the streets, where there is interference with every other class of vehicular and pedestrian travel. As a city grows to the size which is now known as a city of the first class, these conditions arise, the necessities become similar, and gradually the large cities are forced into doing what New York is doing at the present time, viz., to install transit lines either above or below the surface, so that rapid transit service may be carried on without interference with other transportation and thereby obtain a greater measure of rapidity and safety in the service. In the city of London this condition arose many years ago, earlier possibly than would be the case in most American cities, on account of the narrow streets and the consequent tremendous surface congestion. With broad avenues or streets the period of congestion is postponed, so that the necessity for transit lines either above or below the surface is not reached at quite as early a period in the growth of a city. Our great cities are not willing to develop elevated railroad lines anywhere near their hearts, on account of obstruction to light and air, the further and serious obstruction to other traffic, and, what is by no means the least objection, the great nuisance of increased noise, so detrimental to the nervous systems of people who must hear the roar of the traffic. At the same time in many of the American cities elevated railroad lines are deliberately, and it seems foolishly, installed in the suburban districts purely on the ground of the cheapness with which they can be constructed, or in order to obtain what is called rapid transit service at a reasonable cost, in districts sparsely populated. This has been deliberately done with the present Rapid Transit Subway in the city of New York, where, in the northern portions of the city, the subway emerges onto an elevated structure and runs over long sections of steel viaducts. To a considerable extent the same has been done in Philadelphia. If any such structures are necessary and are hereafter built, they should be carefully designed and constructed so as to eliminate all noise arising from an exposed light steel structure. This may be accomplished without any great addition in first cost, and with only slightly increased obstruction upon the surface of the ground.

The title which has been adopted in this country for transportation other than on the surface has an unfortunate adaptation, as it involves a good deal of service which is by no means "rapid transit." The service to which these or any lines of public transportation are applied is affected materially, first, by the density of the population, and, second, by the local conditions. At the same time it is readily understood and appreciated that the service is the heaviest at certain hours of the day and lightest at other hours, and, curiously enough, it seems that on most lines the traffic curves correspond very closely; that is to say, granting a certain total daily service given by any line of railroad, whether on the surface, on ferries crossing the rivers, on an underground, or steam railroad line which does a local transportation business within our populous areas, the curves of traffic per hour are very similar, varying, of course, according to the total movement per diem. These curves reach their summit, or peak, in the morning hours in the movement toward the heart of the city between 7 and 9 o'clock, and reach the corresponding peak for the evening outward bound movement between 4:30 and 6:30 o'clock. The Public Service Commission has rather happily designated these movements as "workwards" and "homewards" respectively. The morning peak in one direction, workwards toward New York, reaches its maximum between 8 and 9 o'clock, 7½ per cent in the direction of heavy flow, and in the opposite direction simultaneously 1½ per cent of the entire total traffic in both directions per twenty-four hours; while the homeward peak in the evening—the heaviest and controlling movement—reaches its maximum between 5 and 6 o'clock, when the outward movement is 10.7 per cent, and the simultaneous reverse movement 2½ per cent, of the entire total traffic in both directions for the day. The movement during the middle of the day is very much less, while the movement after midnight is extremely light, and no railroad operates suburban trains at a profit during the wee small hours of the night, but only on account of its general obligation to the public.

The Hudson and Manhattan Railroad Company was organized as a private enterprise, and as an interstate railroad to handle a proposition which is new and unlike any other in New York city or elsewhere. As every one is well aware, the steam railroads handling New York traffic terminate for the most part on the west bank of the Hudson River, whereas the destination of the passengers is almost entirely within the city of New York. Similarly the street railroads have their termini at various points along the Hudson River front, and a very large portion of the traffic is carried from points in New Jersey to these termini for ferriage across the Hudson River to New York city. The Hudson and Manhattan Railroad differs therefore from the ordinary rapid transit railroad in that it is a terminus in the city of New York for the steam railroads terminating in the State of New Jersey, and is a collecting agency in the city of New York for passengers using the steam or surface roads from Jersey City and Hoboken to the suburban districts in New Jersey. The layout of this railroad is now so well known that it is unnecessary to elaborate upon it, except to draw attention to the fact the road has in New York both an uptown and a downtown terminus. The former is located in the shopping district and is convenient to places of amusement, hotels, and the residential district, and the latter is in the heart of the financial and business district. For a road having the short mileage of the Hudson and Manhattan Railroad the traffic concentration is very great, in fact, as great as on any railroad in the city of New York, and in studying the proposition of construction and operation it has been necessary to consider carefully the very great concentration of traffic, and consequently to arrange all the details of construction and equipment for easy, prompt, and efficient handling of the public.

There is no one who will disagree seriously with the statement that the public, taken *en masse*, is like a flock of sheep, extremely difficult to direct or handle; and that it will at all times move in what it considers the lines of least resistance; consequently the public moving as a mass is a very serious problem to be considered by those designing or equipping a transportation line. The treatment of such a proposition must be done with a clear knowledge of the fact that one is dealing not with individuals but with masses or crowds; and while the individuals composing the mass have sense and can be reasoned with and managed, the mass is unreasoning and often unreasonable; consequently nothing can be omitted in the design and equipment of a transportation line which will assist and direct a crowd so that it can have no possible choice in the matter of what it will or will not do. Only by perfect arrangements in this respect can the railroad and its operating officials obtain the best results for the traveling public. To obtain best results has been the constant effort of those who have had to do with the development of the Hudson and Manhattan Railroad.

The original inception of the present system was a tunnel between the foot of 15th Street, Jersey City, and the foot of Morton Street, New York, which had been started many years ago. The company had undergone several reorganizations, and the property was finally acquired by the present holders at a foreclosure sale. The property then consisted of a section of a tunnel, of considerably larger internal diameter than the present tunnels, driven from the New Jersey shore toward New York. It was designed and partially constructed with the idea of being a terminus to be used jointly by the Erie and Lackawanna railroads, and while the construction of this short section made history in engineering, considering that the promoter was really not an engineer at all, the use and operation of it were utterly impossible. The portion of tunnel constructed was 18 feet internal diameter, unnecessarily large for the ordinary street railroad or suburban railroad car, but too small for two cars to pass, and yet the tunnel was designed for a standard steam railroad car, for which it was unsuitable. In the first financing it was most essential to get a tunnel under the river to demonstrate the feasibility of its construction, and after the long history of failure which had attended the early days of the Hudson River Tunnel Company, it was desirable to establish the fact that such a railroad could be built and operated. A plan was therefore prepared by which it was contemplated that the tunnel would be carried to the New York shore of the same diameter as the portion driven from the New Jersey shore, and within this tunnel it was proposed to operate very narrow cars, somewhat along the lines of the cars first operated in the City and South London Railroad tunnel in London. The tunnel was to be equipped with double tracks and operated as a double-track railroad, in order that it might be of some service to the public and at the same time prove the feasibility of its construction and operation. This plan also contemplated adhering to the original location of the road, which provided for a terminal on the surface about midway between the Erie and Lackawanna Railroad stations in Jersey City. It was proposed to divert the street railway cars to this terminus, making it necessary to transfer passengers across a platform from the street railway cars to the narrow tunnels cars and *vice versa*. In New York it was planned to have the narrow tunnel cars come to a depressed station at Christopher and Greenwich streets, making the terminus at that location adjacent to a surface car line in New York. Such an operated tunnel would have simply been a connecting link between the street railroads in Jersey City and Hoboken and the street railways in New York. It was very easily proved that such a proposition, operating narrow cars as individual units, would not be sufficient in capacity or rapid enough to handle the traffic, and could not earn sufficient money to pay the interest on even the comparatively small capitalization necessary to complete, equip, and put in operation the doubletrack railroad in the single tube. The next step was to complete a second tunnel with similar termini, making a double-track railroad, through which could be operated standard street railway cars. Such a proposition would not be feasible, as no one operating a tunnel railroad of this character would agree to operate it with anything but cars of steel and fireproof construction. With the use of such cars no speed could have been attained except by coupling the cars and forming trains. The undertaking proceeded on this general idea, but it was planned to construct the street railroad cars of steel and to couple them into trains and operate such trains through the tunnels with a full system of signals. The second tunnel was designed not only to take street cars, but also larger cars, if later on it were found desirable to equip the tunnels with larger cars for regular suburban service. It was found that the termini as contemplated were poorly located for convenience of public service and quite inadequate and insufficient for practical use in handling a volume of business large enough to insure getting returns from the capital necessary; and considering that a public utility is primarily for the public use, it was decided not to spare any expense and to overcome all difficulties so as to make the project of the greatest service to the public. The terminus in

* Proceedings of the Engineers' Club of Philadelphia.

New Jersey was the first one changed, and the location adopted was at the Lackawanna Railroad terminus in Hoboken, where all the surface and trolley lines of the Public Service Corporation of New Jersey from the north end of Hudson County terminate, and where the Lackawanna Railroad brings a large suburban traffic over its lines. When the first tunnel was connected under the river to New York, application was made to the Rapid Transit Railroad Commission for authority to change the location of the terminus in New York, for which the earlier franchise had been obtained, to a point where it would be of real service to the public as well as an objective point for operation. The result was the location of the terminus at Sixth Avenue and Thirty-third Street.

Such is the brief history of the development of the Hudson and Manhattan Railroad, and it may be of interest to present various points which have been carefully studied, considered, and adapted for its particular business and special needs, whereby the company has endeavored to carry out arrangements which place this road, it is believed, ahead of all others that have been installed in combining convenience and ease of operation with the least possible friction and discomfort to the traveler, and with the greatest possible efficiency and economical handling of traffic.

Capacity.—The first essential in the study of this railroad was to decide definitely on the capacity for transportation that could be furnished during the hour of maximum travel, as this factor is the basis for regulating everything that comes after. The dimensions of the property which could be acquired for stations, either downtown in New York or at Hoboken where it was necessary to locate upon private property and not under the public streets, fixed the greatest length of train that could be accommodated at 400 feet. The curvature of the railroad as laid out, particularly the short curves (radius 90 feet) entering and leaving the Church Street terminal, made it necessary that the cars should be as short as possible and the truck centers so spaced as to reduce the overhang of the cars on curves to a minimum. The cars in the Rapid Transit Subway in New York are 52 feet long, but this length proved to be too great for the Hudson tunnels, as an eight-car train would be in excess of the maximum length of train that could be accommodated on a tangent in the stations. After considerable study the length of car determined was 48 feet 3 inches when coupled, with distance between truck centers 33 feet. All clearances in the tunnels and approaches had, therefore, to be figured in relation to this particular size of car. The clearances in the tunnels allow for a car of the same width as the original subway cars (8 feet 10½ inches), which makes a roomy car, satisfactory for passenger use. The height of the car, which does not affect the comfort of passengers, was of necessity made low on account of the clearances. The length of train determined upon was eight cars, a total length of 386 feet. A speed curve diagram was then calculated on the fixed characteristics of the railroad, the train weights, and on the assumption that motor equipment would be installed on the cars to operate at a maximum speed of 45 miles per hour on level tangent. The speed is reduced for station and junction controls, on curves, and, of course, on grades. It was figured that station stops would be thirty seconds. Experiments with the air-brakes determined the safe braking distance on various grades throughout the tunnels at which the cars loaded and operated at the calculated theoretical speeds could be properly controlled. The safe braking distance determined the spacing of signals, and as the signal system is the double overlap type (that is to say, the position of a given signal ahead is indicated to an approaching train at two signal stations previous) the spacing of signals throughout the tunnels provides for the closest possible operation permissible under ninety seconds headway with eight-car trains. The railroad is being operated on this interval successfully and regularly. The train load and the minimum train interval indicate that it is possible to operate any portion of the road to the extent of carrying 32,000 passengers in one direction in one hour. All the remaining factors entering into the design of a railroad operated for passenger service depend, therefore, on this one essential prime factor—maximum capacity.

Stations.—As in almost every road laid out, the general location of stations is one of the easiest matters to decide upon. The questions involved are what points offer the greatest facility for the collection and distribution of passengers, and how frequently stations should be located. In this particular case the solution was even more simple than usual. A terminus downtown in the heart of the business district was essential, and its general location had to be within quite narrow limits. The exact location was fixed by the property which could be acquired near Broadway, between Fulton and Cortlandt streets. The short length of, and the physical conditions on, the downtown line led to the conclusion that there would be no station but the terminal, and as arrangements had already been made with the Pennsylvania Railroad for a connection and for interchange of business, the first station in Jersey City was obviously under the station and tracks of the Pennsylvania Railroad. At Hoboken arrangements previous to this had been made for the occupancy of the under-surface of property of the Public Service Corporation at the point where its trolley system terminates near the ferry; and fortunately this location was adjacent to the Delaware, Lackawanna and Western Railroad station, so the use of this private property fixed the station at this point. The tunnels extending from Hoboken to the Pennsylvania station pass under the property and yard of the Erie Railroad, so a station was located at Pavonia Avenue for the interchange of passengers with the Erie Railroad and also with the trolley cars of the Public Service Corporation. These points practically control all the local street railroad business of Jersey City and Hoboken as well as the great bulk of the steam railroad business coming to New York.

In New York city uptown the local conditions make it necessary to have stations at close intervals to give proper facilities to the public and to connect with the intersecting street railway lines, elevated railroad lines, etc. It was undesirable to locate stations, even for local business, closer than 1,200 to 1,500 feet, which makes but a short distance for passengers to walk to or from intervening points, and if the stations were located closer than 1,200 feet the trains could not gain sufficient speed between stations to give adequate service. In the case of Hudson and Manhattan Railroad, the stations, except on Sixth Avenue, are few and at long intervals. The distance from Church Street to the Pennsylvania station is 1.25 miles, from Hoboken to Christopher Street 2.01 miles, and from the Pennsylvania station to Hoboken, with only one intermediate stop—Erie Station—is 1.75 miles; consequently very fast service can be given.

Having decided upon the general location of the stations, the next point was to determine upon a design for stations with a view of providing every facility and convenience for the traveling public. When a railroad has to provide facilities for handling a concentrated travel of 32,000 passengers per hour in one direction, and when that volume of traffic is likely to have one point as its destination, as, for instance, Church Street Terminal, New York, and to a less extent the terminal at Hoboken, then the design of the station is all-important, and it is particularly important with respect to regulating the length of time of station stops, so as not to hamper operation and interfere with the regular maintenance of the prescribed train interval. Some years ago it was thought necessary by railroad men to have at a station a large number of tracks where trains could stand a considerable time while being unloaded and loaded. The conditions of suburban rapid transit service have necessitated a radical change from this old theory. A steam railroad train made up of coaches equipped with platforms and steps at the ends by which passengers must leave and enter can only unload and load, even in the most rapid suburban service, at the rate of approximately 30 passengers per minute per car. For steam railroad trains with cars having a seating capacity of about 60 passengers, and no necessity whatever for making a short station stop, this rate of handling passengers is still permissible; but with rapid transit service, where it is not unusual to have a total of 115 passengers per car, this rate would be impossible. Cars equipped with end doors at the level of the station platform, as in the older types of elevated and subway cars, permit the movement of only one person through a car door at one time. It requires sixty seconds to unload a car of this type, and if the train is then reloaded at the same point, it requires thirty seconds to take on, say, one-half a carload. As the movement in the contrary direction is never as heavy as the movement in the maximum direction, and as the loading process cannot be begun until the unloading is completed, it is obvious that this interval would be prohibitory under conditions of maximum service. Further than this, the fact of having a single platform from which to unload and load passengers simultaneously introduces a congestion on the platform which delays materially this movement and lengthens the necessary station stop. Even the movement on street cars in or out is only at the rate of 50 passengers per minute through end openings, and if one end is closed, as in some of the modern cars of the pay-as-you-enter type, when operated at terminals it is not unusual for passengers to enter at a rate of only 17 or 18 persons per minute, and consequently to get a car loaded at such a slow rate as this interferes materially with the capacity of the road.

At the Hoboken Terminal the Public Service Corporation has lately completed a terminal station, which is a new departure and ideal for handling efficiently these types of cars. The station is inclosed, and every passenger must buy a ticket and put it into a chopping-box before entering the station; the conductor has only to collect fares from passengers who get on after the car has left the terminal station. In street service passengers usually get on or off in small numbers at any place other than terminals, and so if these terminal points are cared for, there is little difficulty in handling the passengers.

The result of numerous observations of all possible combinations shows clearly that the essential requirement of all station design for handling large crowds at terminals is to separate the movement of passengers so that cars are unloaded from one side and loaded from the other. This does not necessarily apply at local stations, where passengers are comparatively few and well distributed; the movement can be made within the allowable thirty-second station stop and with comparatively little inconvenience to the public. The Church Street terminal (New York), Hoboken terminal, and the stations now being constructed at Thirty-third Street and Broadway, New York, and at Summit Avenue, Jersey City, therefore, are arranged with platforms at the level of the car floor and with provision for loading trains from a platform on one side and unloading onto a platform on the opposite side.

The next point to be considered in designing the station is the arrangement for handling passengers between trains and public thoroughfares without conflict in the movement. It is most essential in any railroad proposition to control the movement of passengers as far as possible in the right-hand direction, and so far as possible to deliver the flow of passengers in one direction at points where they will not come in contact or conflict with the passengers moving in the opposite direction. One of the most unfortunate features in an underground system is the necessity for taking passengers from station platforms below the level of the street and distributing them at the street surface, and this necessitates in the cases of slight elevation stairs or ramps, and in cases of great elevation escalators or elevators. The movement of passengers in a straight passage, either on a level or on a reasonable incline of 10 or 12 per cent, is very rapid, and when the movement is approximately in one direction, it amounts to 40 persons per foot of width of passage per minute. Consequently a comparatively narrow passage will accommodate a large number of people in a short period of time. As soon as such a movement reaches a staircase, however, the rapidity is immediately reduced, as the step taken by the passengers is shortened from about 30 inches to approximately 12 inches, so that while the passenger may take the physical step as rapidly as when walking on a level surface, the actual forward movement is perceptibly slower. On broad staircases, moving in one direction only and upward, the number of passengers per minute averages 15 per foot of width, whereas the maximum counted on any staircase under these conditions is 24 per minute. If moving downward, the average per minute under similar conditions is 13 and the maximum is 18. These conditions have to be taken into serious account when the necessity for staircases arises. It is equally obvious that wherever conditions permit, ramps should be provided instead of stairs, as the accommodation provided by a ramp is very much greater and the use of a ramp is materially easier for the passenger.

In the development of Church Street terminal, where the concentration of people is likely to be excessive, there could be no choice in the use of staircases for handling passengers from the platforms to the concourse level, but the height of the concourse above the platforms was made as small as was possible, allowing proper clearances for the trains. The alternate platforms in this station are for loading; the others for unloading, so that the loading platform serves two trains, while the central unloading platform serves two tracks; the exterior platform is for unloading and, of course, serves but one track. The arrangement of staircases from the unloading platforms is tandem on the centers of platforms, and the direction is outward from the center of the platform. There are six staircases to each platform,—three on each side of the center line of the platform,—so that the distance from the exit door of a car to the nearest staircase is very short. These staircases discharge passengers at the concourse floor in a direction pointing south to Cortlandt Street or north to Fulton Street, thus delivering passengers on the concourse floor in the direction they desire to proceed. On the other hand, the staircases to the loading platforms lead from central points on the concourse floor to points along the train platforms, and are so arranged that each loading platform has two pairs, which enables the operating department to group the chopping-boxes at the top of each of the two pairs of staircases and thus reduce, during the slack hours, the expense of ticket-choppers, ticket examiners, guards, etc. Up to the present time no more efficient arrangements have been invented for examining and canceling tickets than the old barriers and chopping-boxes. The arrangement of stairs delivers passengers coming to trains at four points on the loading platforms more or less equally spaced, and provides an equal distribution in the train loading. At the Church Street terminal the space is sufficient to permit of distributing passengers on the concourse floor, so that under the worst conditions of the maximum traffic there will be no congestion on this floor, and the extremely broad ramps to Cortlandt and Fulton Streets and wide staircases to Dey Street provide free ingress and egress to and from the concourse floor.

(To be continued.)

Cement Sidewalk Paving*

Simple Directions for Laying It

By Albert Moyer, Assn. Am. Soc. C.E., M. Natl. Cement Users' Association

Cement sidewalk paving is a manufacturing industry whereby cement stone slabs are framed in place on the job. Paving of this description has various uses. Its principal use is a permanent path for pedestrians. Among the other uses are driveways for vehicles, a floor-wearing surface for buildings, platforms in the stations of transportation lines, wharf coverings, cellar floors, curb

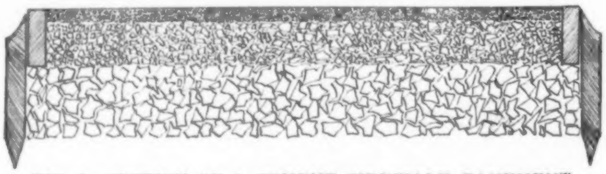


FIG. 1.—SECTION OF A CEMENT SIDEWALK PAVEMENT

and gutters. The principal objects to be accomplished in manufacturing these cement stone slabs for the above named purposes are permanency, durability and neatness.

To accomplish permanency it is necessary that these slabs remain hard, tough and in the original position for the average life of good construction work. To achieve this object, correct methods of manufacture must be employed which will avoid settlement cracks, upheaval by frost and roots of trees, crumbling due to work having been laid in freezing weather, contraction cracks, expan-

FIG. 2.—CONCRETE MIXING PLANT, SHOWING CONCRETE BOARD, TOOLS, ETC., NECESSARY FOR MIXING CONCRETE BY HAND

sion cracks, separation of top from base and disintegration.

To avoid settlement cracks it is necessary thoroughly to ram the ground after excavating for foundation. After drainage foundation has been put in place this should be thoroughly and evenly tamped so as to avoid any uneven strain. The thickness of the slab should be governed by the factor of safety necessary to provide for the weight that is likely to be placed on any one slab. It is estimated that a number of persons can be so crowded together as to cause a weight of from 100 to 150 pounds per square foot. As the strength of the slab is not always governed by its thickness, maximum strength is obtained by properly proportioning the aggregates so that maximum density results.

To avoid upheaval by frost, a proper drainage foundation must be provided, such foundation to be carried to a sufficient depth so as to provide for perfect drainage; a drainage foundation is of use only in the event that it thoroughly drains. Such a foundation is often placed so that it not only fails to acomplish the purpose for which it was intended, but practically defeats that object by causing an accumulation of water which in freezing upheaves the pavement. A drainage foundation should have an outlet which has a fall of about ¼" or over to the foot. If there is no natural outlet for such drainage, blind drain leaders should be provided at points along the walk where they are necessary. These leaders should be formed of similar material as the drain itself with, possibly the addition of a porous drain tile leading into holes filled with cinders or crushed stone which will allow the surrounding earth to absorb the accumulated water.

Upheaval by tree roots can very easily be avoided by cutting out any roots which will run under the pavement less than a depth of six inches under bottom of drainage foundation.

Portland cement concrete expands and contracts in practically the same ratio as steel; it is therefore necessary to cut joints which will allow for this expansion or contraction. The concrete must be cut entirely through with a cleaver, or other instrument, from ⅛" to ¼" wide, the blocks thus formed not to exceed 6' square. I am fully aware that very excellent work has been done, the blocks being as large as from 12' to 14'; that good results were obtained with such large slabs is due more to favorable circumstances than to correct method. By figuring the expansion and contraction per degree between the heat of summer and the cold of winter, it will be found that we are only within the region of safety when the slabs do not exceed 6' with an ⅛" joint between each slab.

Expansion cracks are not due so much to the expansion of the cement stone slabs as to the expansion of other material bearing against these slabs; it is therefore advisable to cut the concrete away from the manholes, iron posts, etc., leaving about the same space in the joints as between the slabs themselves. This space may be readily waterproofed by using felt paper painted with a good waterproof paint.

In the past it has been a very common practice to allow the base to set hard before laying the top coat; it is unnecessary at the present date to dwell on this subject; we all know that it is utterly wrong. There are, however, other causes which prevent the top coat from adhering permanently to the base, the principal cause being carelessness in allowing men to walk over the base carrying with them dust and dirt, also failure to protect the base, allowing the surface of the base to be exposed to the rays of the sun and thus dry the surface prematurely, at the same time allowing dust and dirt to blow over the surface, coating the concrete so that the top when placed fails to adhere permanently. It is also absolutely necessary that the top be cut directly over the cuts in the base; otherwise the top coat will crack along the line of the joint in the base.

The principal causes of disintegration and chalky top surface are insufficient mixing, drying out before ultimate crystallization of cement, and bad material used. Start right and good results naturally follow. To avoid disintegration material should be carefully selected. This selected material must be thoroughly incorporated and

*Reprint of a bulletin published by Vulcanite Portland Cement Company.

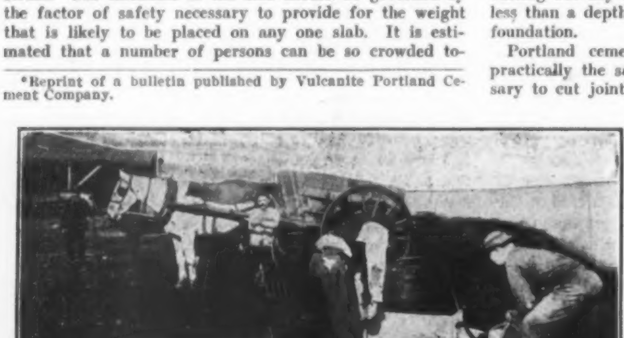


FIG. 3—LIFTING OFF THE SAND-MEAURING BOX AND GETTING CEMENT READY

FIG. 4.—SPREADING THE CEMENT OVER THE SAND

mixed into a plastic mass with sufficient water to bring about ultimate crystallization of the cement. Being thus mixed it should be immediately placed upon a cinder or broken stone foundation which has to be *soaked with water*, thoroughly and evenly tamped and then protected from drying out before final setting. Cement needs water, not only when mixed, but after being placed and tamped, and it requires water until ultimate crystallization has taken place. If any portion of the concrete is robbed of the amount of water necessary to bring about this result, the concrete is weakened to that extent.

It is important that the best material be used in the manufacture of Portland cement sidewalks. Poor material makes poor walks and costs just about as much.

Having selected the best materials obtainable, by far the most important operation is that of mixing. The methods employed in mixing by hand as well as by machinery depend largely upon the character of the aggregates used. It is now being almost universally recognized that the small aggregates, properly graded in size, make the densest, strongest and best concrete for sidewalk paving. Mix a concrete made of gravel, three-quarter inch hard limestone, traprock or other hard, tough stone, and good coarse sand, by first mixing the cement and sand dry.

Following is the best procedure for hand mixing graphically described. (Written by Percy H. Wilson and Clifford W. Gaylord.)

The permanency of the pavement depends on careful and thorough mixing.

Showing the Quantities of Materials and the Resulting Amount of Concrete for Two-bag Batch, Using Natural Mixture of Bank Sand and Gravel.

Kind of Concrete Mixture.	Proportions by Parts.			Two-Bag Batch.						
				Materials.				Size of Measuring Boxes. Inside Measurements.		
	Cement.	Sand.	Stone or Gravel.	Cement, Bags.	Sand, Cubic Feet.	Stone or Gravel, Cu. Ft.	Concrete, Cubic Feet.	Sand.	Stone or Gravel.	Water, in Gallons, for Medium Wet Mixture.
1 : 2 : 4 concrete	1	2	4	2	3¾	7½	8¼	2' × 2' 11½"	2' × 4' 11½"	10
1 : 2½ : 5 concrete	1	2½	5	2	4¾	9½	10¼	2' × 2½' 11½"	2' × 5' 11½"	12
1 : 3 : 6 concrete	1	3	6	2	5¾	11¼	12	2' × 3' 11½"	3' × 4' 11½"	13½

Showing the Quantities of Materials and the Resulting Amount of Concrete for Two-bag Batch.

Kind of Concrete Mixture.	Proportions by Parts.		Two-Bag Batch for Natural Mixtures of Bank Sand and Gravel.				
			Materials.			Size of Measuring Boxes.	
	Cement.	Natural Mixture of Sand and Gravel.	Cement, Bags.	Natural Mixture of Sand and Gravel, Cubic Feet.	Concrete, Cubic Feet.	Mixture of Sand and Gravel.	Water, in Gallons, for Medium Wet Mixture.
1 : 2 : 4 concrete......	1	4	2	7½	8¼	2' × 4' × 11¼"	10
1 : 2½ : 5 concrete....	1	5	2	9½	10¼	2' × 5' × 11¼"	12
1 : 3 : 6 concrete......	1	6	2	11¼	12	3' × 4' × 11¼"	13½

With the proper materials selected, the next step is to mix properly and with dispatch. On large jobs it is more economical to mix concrete by machine, but for small jobs, using even as much as several hundred cubic yards of concrete, it is much cheaper and more expedient to mix by hand. This is, of course, especially true when only two or three men are available and the work is often in-

FIG. 5.—FIRST TURNING, SAND AND CEMENT

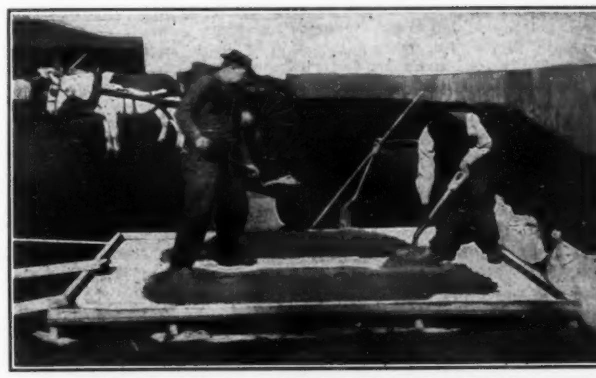


FIG. 6.—SECOND TURNING, SAND AND CEMENT

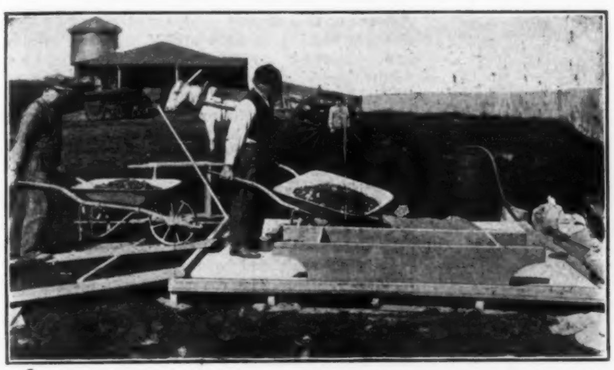


FIG. 7.—FILLING THE STONE (OR GRAVEL) MEASURING BOX FIRST METHOD

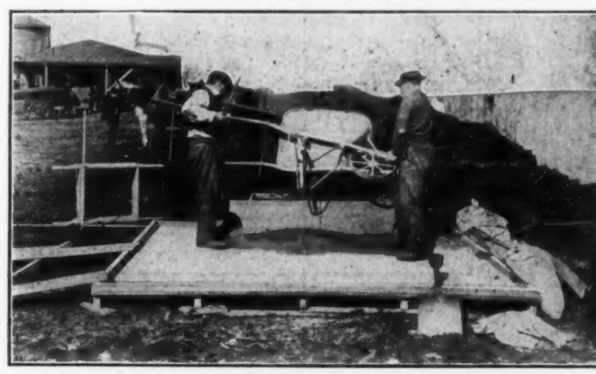


FIG. 8.—FILLING THE STONE (OR GRAVEL) MEASURING BOX WHEN ON TOP OF MIXED SAND AND CEMENT—SECOND METHOD

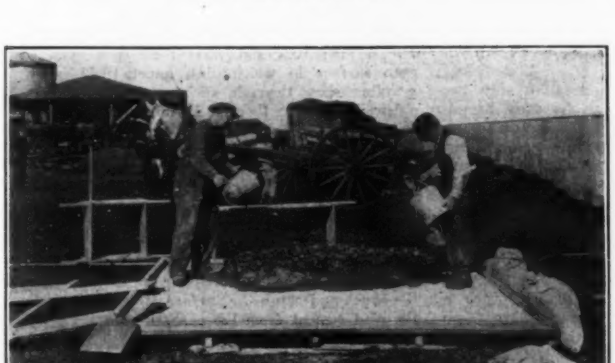


FIG. 9.—PLACING THE WATER ON THE STONE (OR GRAVEL) WHICH IS ON TOP OF THE MIXED SAND AND CEMENT

FIG. 10.—MIXING THE STONE (OR GRAVEL) WITH THE SAND AND CEMENT

FIG. 11.—CONCRETE MIXED AND READY FOR PLACING

FIG. 12.—PLACING THE CONCRETE WITH WHEELBARROWS

terrupted. There are many ways of "hand mixing," all having the same good results. The way described here we believe to be the one best calculated to obtain good results with a minimum of labor. In this description and the accompanying illustrations, we have taken as a basis a "Two-Bag Batch."

A concrete board for two men should be 9 feet × 10 feet. Make it out of 1-inch boards, 10 feet long, surfaced on one side, using five 2-inch × 4-inch × 9-foot cleats to hold them together. If 1-inch × 6-inch tongue and groove roofers can be obtained, they will do very nicely if fairly free from knots. The object of the surface boards is to make the shoveling easy. The boards are so laid as to enable the shoveling to be done with, and not against, the cracks between the boards. The boards must be drawn up close in nailing so that no cement grout will run through while mixing. Knot holes may be closed by nailing a strip across them on the under side of the board. It is a good precaution against losing cement grout to nail a 2-inch × 2-inch or 2-inch × 4-inch piece around the outer edge of the board. Often 2-inch planks are used in making concrete boards, but these are unnecessarily heavy and very cumbersome to move.

Placing the Concrete Board.—The concrete board is a manufacturing plant, and the advantages of its location should be carefully considered. Generally it is best placed as close as possible to the place in which the concrete is to be deposited, but "local conditions" must govern this point. Pick a place giving plenty of room, near the storage piles of sand and stone (or pebbles). Block up your concrete board level, so that the cement grout will not run off on one side, and so that the board will not sag in the middle under the weight of the concrete.

Do not use any old boards that are handy for the wheelbarrow runs. Make a good run, smooth, and at least 20 inches wide if much above the ground. It is surprising how this one feature will lighten and quicken the work.

List of tools and plant to be used in mixing, giving sizes, quantities, etc.:

Concrete board for two-bag batch, 9′ × 10′ in size:*

Nine pieces 7/8″ × 12″ × 10′, surfaced one side and two edges (any width of plank may be used; 12″ is specified only for convenience); 5 pieces 2″ × 4″ × 9′ rough; 2 pieces 2″ × 2″ × 10′ rough; 2 pieces 2″ × 2″ × 9′ rough.

two bags of cement and place the contents as evenly as possible over the sand. (See Fig. 4.) With the two men Fig. 5 start mixing the sand and cement, each man turning over the half on his side. Starting at his feet and shoveling away from him, each man takes a full shovel load, turning the shovel over on their own side. In turning the shovel, do not simply dump the sand and cement near the edge of the concrete board, but shake the materials off the end and sides of the shovel, so that the sand and cement are mixed as they fall. This is a great assistance in mixing these materials. In this way the material is shoveled from one side of the board to the other, as shown in Figs. 5 and 6; Fig. 5 shows the first turning, and Fig. 6 the second turning.

The sand and cement should now be well mixed and ready for the stone and water. After the last turning, spread the sand and cement out carefully, place the gravel or stone measuring box inside it as shown in Fig. 7, and fill from the gravel pile. Lift off the box and shovel the gravel on top of the sand and cement, spreading it as evenly as possible. With some experience equally good results can be obtained by placing the gravel measuring box on top of the carefully leveled sand and cement mixture, and filling it, thus placing the gravel on top without an extra shoveling. This method is shown in Fig. 8. Add about three-fourths the required amount of water, using a bucket and dashing the water over the gravel on top of the pile as evenly as possible. (See Fig. 9.) Be careful not to let too much water get near the edges of the pile, as it will run off, taking some cement with it. This caution, however, does not apply to a properly constructed mixing board, as the cement and water cannot get away. Starting the same as with the sand and cement, turn the materials over in much the same way, except that, instead of shaking the materials off the end of the shovel, the whole shovel load is dumped and dragged back toward the mixer with the square point of the shovel. This mixes the gravel with the sand and cement, the wet gravel picking up the sand and cement as it rolls over when dragged back by the shovel. (See Fig. 10.) Add water to the dry spots as the mixing goes on until all the required water has been used. Turn the mass back again, as was done with the sand and cement. With experienced laborers, the concrete would be well mixed

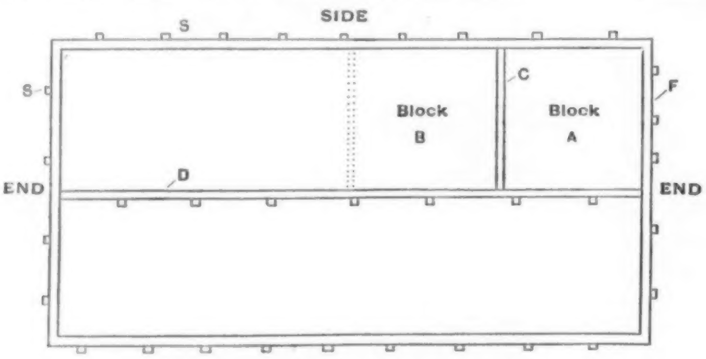


Fig. 13.—SEPARATION OF SLAB OR BLOCKS

C—Wooden strips 2 x 3-inch lumber (movable).
D—Long wooden strips 2 x 3-inch lumber (movable).
F—Wooden frames 2 x 4-inch lumber, top of which coincides with established grade of walk.
S—Stakes for holding frame in position.

Concrete board for four-bag batch, 12′ × 10′ in size:

Twelve pieces 7/8 × 12″ × 10′, surfaced one side and edges (any width of plank may be used; 12″ is specified only for convenience); 5 pieces 2″ × 4″ × 12′ rough; 2 pieces 2″ × 2″ × 10′ rough; 2 pieces 2″ × 2″ × 12′ rough.

Runs.—2″, 2½″, or 3″ plank 10″ or 12″ wide.

Measuring boxes for sand and stone or gravel.

For two-bag batch 1:2:4 mixture:

Four pieces 1″ × 11½″ × 2′ rough; 2 pieces 1″ × 11½″ × 4′ rough; 2 pieces 1″ × 11½″ × 6′ rough.

Note—The 2 pieces 4′ long and the 2 pieces 6′ long have an extra foot in length at each end to be made into a handle, as shown in Fig. 2.

For two-bag batch 1:3:6 mixture:

Two pieces 1″ × 11½″ × 2′; 2 pieces 1″ × 11½″ × 3′; 2 pieces 1″ × 11½″ × 5′; 2 pieces 1″ × 11½″ × 6′.

Note—The 2 pieces 5′ long and the 2 pieces 6′ long have an extra foot in length at each end to be made into a handle, as shown in Fig. 2.

For four-bag batch:

Double cubic contents of boxes and order lumber accordingly.

Shovels.—No. 3 square point.

Wheelbarrows.—At least two necessary for quick work; sheet-iron body preferred.

Rake.

Water-barrel.

Water-buckets.—Two-gallon size.

Tamper.—4″ × 4″ × 2′ 6″, with handles nailed to it, as shown in Fig. 2.

Sand Screen.—Made by nailing a piece of ¼″ mesh wire screen 2½′ × 5′ in size to a frame of 2″ × 4″.

With the mixing board placed and the "runs" made the concrete plant is ready.

First load your sand in wheelbarrows from the sand pile, wheel on to the "board," and fill the sand-measuring box, which is placed about two feet from one of the 10-foot sides of the board. When the sand box is filled, lift it off and spread the sand over the board in a layer three inches or four inches thick, as shown in Fig. 4. Take the

*For convenience the signs ′ for feet, and ″ for inches, have been used in describing tools and plant in tables.

after three such turnings; but if it shows streaky or dry spots, it must be turned again. After the final turning, shovel into a compact pile. The concrete is now ready for placing. (See Fig. 11.)

Number of Men.—For the above operation only two men are required, although more can be used to advantage. If three men are available, let two of them mix as described above and the third man supply the water, help mix the concrete by raking over the dry or unmixed spots as the two mixers turn the concrete, help load the wheelbarrows with sand and stone or gravel, etc. Fig. 5 shows a third man on the board. In this illustration he is helping mix the sand and cement by raking it—a most effective practice.

When the day's work is done, carefully clean all the tools, especially the concrete board. Remove with a shovel all the loose cement, sand, and stone. Then scrub the board with a broom and water. If this is not done, small particles of stone are glued to the board by the cement, and render shoveling the next day most difficult.

We again wish to call attention to the fact that there are several ways of mixing concrete by hand, just as effective in their results as the ways mentioned here. But every man of experience in mixing has one way which he thinks is more effective and easier than any other.

Machine mixing should be accomplished much the same as it is in Germany, the mortar mixed dry, then the stone added, then the whole mass mixed dry; this entire mass is then run into another mixer and there mixed wet. This result can be fairly well accomplished by using a mixer which has knives and rakes, which does the same thing as turning and raking in the hand mixed process; understand, I am advocating this method only for concrete made up of small size aggregates, that is, all passing a ¾″ mesh.

Dry concrete, even though thoroughly tamped, seldom gives thoroughly satisfactory results.

The object to be accomplished in laying a base for a sidewalk is uniform strength. The concrete to be of such consistency as will enable the workmen to place the top coat over the base during the same day and before the base has finally set. If the concrete is very wet, such as poured concrete, a scum forms on the top surface which interferes with the proper adhesion of the top coat to the base. Therefore, a happy medium should be found bringing about proper consistency which may be thoroughly and uniformly tamped. This can only be judged by the eye on the mixing board and is a matter which necessarily has to be left to experience.

The concrete should not be made so wet that it will quake under the tamping iron, unless steel strips are used for the joints or laid in alternate blocks; it should be sufficiently wet, however, so that some moisture rises to the surface under the tamping. The proportion of water necessary will vary according to the climatic and other surrounding conditions. The proper consistency can only be judged by the eye on the mixing board; no accurate specifications can possibly bring about uniform and desirable results. This is a matter which necessarily has to be left to experience. The tamping should be vigorous and uniform.

One of the causes of bad workmanship is due to the concrete either in the top or the base, having prematurely dried. This is avoided by keeping the concrete covered to protect it from wind and the rays of the sun. If the concrete is anywhere near boilers or steam pipes, see to it that the concrete is wet continuously for from twenty-four to thirty-six hours; after this period sprinkle two or three times a day for a couple of weeks, or such length of additional time as economy will permit. Sidewalk paving slabs are acted on from both sides; and, being comparatively thin, are more sensitive than mass concrete, therefore need greater protection. The writer has seen instances where workmanship as far as selection of materials, mixing, placing and tamping were thorough and excellent; but, nevertheless, bad results were obtained. This was particularly true of a pavement laid over waterproofing. The atmosphere absorbed the moisture from the top and the top absorbed the moisture from the base. The base had nothing wet under it from which to get water, could not supply sufficient moisture to the top to offset the action of the dry air, and the result was a top of chalky consistency. Had the base been made very wet and the top covered with wet sand, no such results would have been produced.

Durability relates principally to the wearing surface; there is no reason why a cement slab should not wear longer than the ordinary natural stones; for, in forming these slabs we have the advantage of selecting the toughest and strongest stones. Cement itself is tougher and stronger than most of the products of nature. The texture of the surface has a good deal to do with efficiency. A scum or skin of neat cement on the surface soon wears through, causing an ugly and blotchy pavement. There is no reason why a slab of cement stone cannot be manufactured which would wear for a hundred or more years; it might wear down to the extent of half an inch, or an inch or more, and still preserve the same texture. This is perfectly feasible by making a slab of one piece, no top coat whatever, an even smooth top, carefully jointed, composed of small selected aggregates and in proportions which result in maximum density. I have seen one or two pavements of this character, notably the one around the Hotel Astor, New York, which is in 9″ slabs entirely around the building, expansion joints cut at regular intervals and so arranged as to form an architectural design. The concrete was composed of three-quarter inch traprock and sand. The surface was floated off and smoothed down with a trowel; it was not troweled to such an extent as to bring any neat cement to the surface. This pavement will wear for two hundred years or more, and as it wears down the same texture is preserved.

The usual troweled surface is slippery; it is subject to all manner of diseases, such as hair cracks, crazing, peeling, etc., and is only beautiful before the disease sets in. A monolithic slab leveled off and smoothed to an even surface in which flint, quartz pebbles or crushed granite show through, such as some of our granolithic sidewalks, can be thoroughly tamped and then floated so that the above desirable results are economically obtained. Another method is to use three-quarter inch hard stone, and quarry screenings or sand, making a monolithic slab, straight edge off, tamp uniformly, smooth down to an even surface with float and trowel, cut joints, carefully mark joints with a good jointer, round the edges, and after final set is reached, but before the surface has begun to dry, scrub with a steel brush such as is used in cleaning boilers; play a hose on the surface just ahead of the brush and scrub the surface vigorously. This removes the neat cement from the exposed surfaces of all the aggregates, does not disturb the aggregates, and gives a most beautiful, natural and genuine finish, similar to natural granite; you therefore have a pavement which is honest and genuinely clear through and is obviously so.

The object of a top coat is durability, at the same time properly serving the purpose for which it is intended, that of foot traffic. A slippery sidewalk is a menace to humanity.

In order to obtain durability, neatness and good service, the top should be worked to a flat surface with a straight edge and smoothed down evenly with a float. After the surface water has been absorbed and just as the top is hardening, it should be slightly troweled, but not enough to bring the neat cement to the surface, at the same time being careful to get an even surface avoiding float and trowel marks.

Neatness is obtained by the texture produced as described above, by carefully marking the joints and rounding the edges. Be careful not to use too much water so that an excess of water rises to the top, carrying with it particles of neat cement. This causes hair cracks, crazing, streaks and efflorescence. Another disease is occasioned by an accumulation of water in any one or more places which will cause what has been commonly known as water cracks, which are not open cracks, but surface cracks, and look like dark blotches. In discussing this

subject of neatness, observation would indicate that the thought uppermost in the mind of most sidewalk paving contractors had been that of forming an artificial top of veneer over the rougher concrete. Do not use lamp black, it is the worse form of poor imitation. Sidewalk paving construction, like all other forms of engineering, is only permanently and lastingly good if honest and genuine. We will sum up the foregoing into the following suggested specifications:

SPECIFICATION SUGGESTIONS.

Sidewalks in cold climates where frost occurs should consist of a foundation of coarse cinders, broken stone, brick-bats, or other porous material, the concrete to be laid on this foundation. Do not lay concrete in freezing weather.

Excavate to a sufficient depth so as to provide for perfect drainage, ram and tamp the ground thoroughly and evenly, provide clean large cinders, broken stone, or brick-bats, any of which should be collected on an inch mesh; place these to within the needed distance of the top of the established grade of the pavement (a sufficient number of inches to provide for the thickness of slab necessary to give adequate strength for the character of the work it is to perform), tamp this drainage foundation well and evenly, thoroughly wet to saturation the cinders, stone or broken brick, place in position wooden forms in a manner necessary to accurately outline the top and external edges of the walk, the top of the form being located so as to coincide with the established grade of the walk, place stakes nailed to and on the outside of forms or broad strips. As an additional precaution, and where necessary to accomplish the purposes of drainage, side drains should be placed every ten or twelve feet, having a fall of not less than one-quarter inch to the foot, leading to some point forming an outlet for water which may accumulate. This outlet should be below the frost line and it may be accomplished by a hole filled with cinders, stone or brick-bats. Cut out the roots of trees which lie less than a depth of six inches under the bottom of the drainage foundation.

For a concrete base, spread enough material to provide for the thickness of a slab which will come to within one inch of the top of the established grade; this concrete to be composed of one part Portland cement and two and a half parts sand or quarry screenings, all passing one-quarter-inch mesh, and five parts broken stone or gravel, all passing one-inch mesh and collected on a quarter-inch mesh; mix thoroughly.

The specifications may be regulated if proportions can be obtained which will allow of a larger proportion of broken stone, at the same time giving maximum density. Tamp the concrete to an even thickness, cut the same into uniform squares of not over six feet square, using a steel cleaver of not less than one-eighth inch and not over one-quarter inch in thickness. Cover the base with tarpaulins or tar paper immediately as each section is laid, this as a protection against dust, dirt or premature drying. Mark on the wooden forms the exact locations of these cuts. After each batch of concrete is laid as required, and before the base has started to harden, it shall be covered with a top coat, or wearing surface, no dirt or dust having been allowed to accumulate on the base and the surface of the base to be wet or moist. Any portion of the foundation which has been left long enough to have the appearance of setting or hardening shall be taken up and re-laid before the top coat is put on.

In order that the pavement may drain off readily during and after rain, the surface should be graded toward the street, having a fall of one-quarter of an inch to the foot, causing the top nearest the street to be lower than the top nearest the buildings.

For wearing surface mix one part Portland cement with two parts crushed granite or other hard stone (all of which will pass through a quarter-inch mesh screen), or good coarse sand; mix by turning with shovels, raking with a garden rake as each shovelful is turned, turn twice dry and twice wet, add sufficient water to make a plastic consistency so that when floated or troweled very little water rises to the surface. Spread this mortar over the concrete base to a thickness of one inch. Work to a flat surface with a straight edge, smooth down with float and trowel after the surface water has been absorbed; be careful to get an even surface, bringing no neat cement to the surface and avoiding float and trowel marks.

Cut the top surface directly over the cuts made in the base, cut entirely through top and base all around each block. Finish the joints thus made with a jointer and round or bevel all edges.

At the end of the day's work some careless workman often ends the work with an incline of concrete, and when the work is started the next morning new concrete is spread over this incline of concrete which has set hard. While a bond may result it will at best be very weak, resulting during the course of a month or two in a crack at this point.

The day's work should be ended at the end of a slab. A form should be staked across making a vertical joint, a piece of thick tar paper should be placed against this vertical joint and the new concrete placed against this tar paper.

As an alternative and instead of using a top coat, make one slab of selected aggregates for the face and wearing surface, filling in concrete between the frames flush with the established grade. Concrete must be of selected aggregates all of which will pass through a three-quarter-inch mesh sieve, hard tough stones or pebbles graded in size, proportions to be one part cement, two and a half parts crushed hard-stone screenings or coarse sand (all passing a quarter-inch mesh), and five parts crushed hard-stone or pebbles, all passing through a three-quarter-inch mesh, and all collected on a quarter-inch mesh; tamp to an even surface, prove surface with a straight edge, smooth down with float or trowel. Thoroughly mix.

Do not allow any block to bear directly against any solid body, such as stone curb, building, post, manhole rim, etc. Leave the same space (about one-quarter inch) between the pavement and such fixtures as are between the blocks themselves. This applies to the base and top as designed to avoid cracks and chipping due to expansion and contraction from temperature changes. This space can be conveniently provided for by the use of thick tar paper or felt, waterproofed with any of the reliable waterproof paints.

When finished, cover the pavement so as to protect it against the rays of the sun, the wind and consequent drying, raising the covering a few inches so as not to come in contact with the surfaces; after the pavement has reached hard set, sprinkle frequently two or three times a day with a garden hose or a sprinkler for a week or more.

SIDEWALKS.

Another method designed to insure perfect separation of slab or blocks. (See Fig. 13.)

Place a 2×3-inch strip *D* parallel with the side of the walk, in such position as will form square blocks, of equal dimensions, not over six feet wide; brace the same with stakes, but do not nail to the frame, then cut a strip 2×3 inches, the length of which is to be the width of the blocks, or distance between strip *D* and side frame *F*. Place this strip so as to form a square block *C*. On the inside of the strip *C* and *D* place thick tar or felt paper ¼ inch thick and 3 inches wide; fill in the space thus formed (block *A*) with concrete composed of one part Portland cement, two parts sand and five parts crushed stone or gravel, and mix thoroughly. Tamp the concrete thoroughly to an even thickness, then remove strip *C*; the tar paper will adhere to the concrete. Move strip *C* to the next position, skip block *B*, place the thick tar or felt paper as before, and proceed the same with each block laying alternately. Put on the top coat before the first block made starts to set or harden, and in regular order as blocks were made.

CEMENT SIDEWALKS IN WARM CLIMATES WHERE FREEZING DOES NOT OCCUR.

Excavate to a depth of 4 inches below established grade of the sidewalk, tamp the ground well and evenly, omit the cinder or broken stone drainage foundation; remainder of specification same as that for sidewalks in cold climates.

DRIVEWAYS.

Base should not be less than 4½ inches thick.

Wearing surface should not be less than 1½ inches thick; remainder of specification same as for sidewalks.

CELLAR FLOORS.

Use sidewalk specification with the exception that the cellar should be waterproofed outside the sides, carrying the waterproofing down outside of the wall over the top of the footings; in addition lead off water by outside drainage obtained by porous drain tile covered with cinders or broken stone run around the wall just below the top of the cellar floor, leave out the drainage foundation and do not cut the concrete into blocks. A two-inch to four-inch thickness is sufficient.

COLORING MATTER.

Do not use coloring matter unless absolutely necessary. Nearly all coloring matter reduces the strength of the mortar. For coloring cement work the following quantities will be found the least objectionable.

QUANTITIES PER 95 POUNDS OF PORTLAND CEMENT.
For a 1:2 mortar.

		Pounds.
Black	Excelsior carbon black	2
Black	Manganese dioxide	10
Buff	Yellow ocher	4
Blue	Ultramarine or azure blue	4
Gray	Lamp black (bone black)	½
Green	Ultramarine	5
Green	Oxide of cromium	7
Brown	Roasted iron oxide	6
Red	Red iron oxide	6 to 10
Bright red	Pompeian red	6
Yellow	Ocher	6

Mix the coloring matter thoroughly with the sand or screenings in proportions as above.

CEMENT CURB AND GUTTER.

The drainage foundation should be of materials as described under the head of sidewalk paving, and placed so as to accomplish the object of drainage, using the methods and instructions as previously described.

Place in position the forms to receive the concrete. These forms are held in place by stakes set by the engineer at points necessary to accurately designate the line and grade of the proposed curb and gutter. (See Fig. 14, *A*, *B* and *S*.) For forms use 1½ to 2-inch rough planks. Dimensions to be according to the height of the curb and thickness of the gutter. Form *F* is movable and is held in place by iron clamps bearing against the outside of form *B*, extending over the top of the curb, this clamp being shaped similar to the letter C, one of the arms being fitted with a screw.

Spread five or more inches of concrete mixed as described under the head of Cement Sidewalk Paving. The concrete should be mixed wet so that when tamped some water will come to the surface. Then place in position form *F* and fill in with concrete the same mixture between form *F* and form *B*, tamp thoroughly and evenly to within one inch of the top of the curb; form *F* may be taken down immediately and moved to next position. Form *B* will be found sufficient to hold the concrete curb in place without sagging. Cut curb and gutter entirely through every six feet. A convenient and sure method is to use a piece of quarter-inch sheet iron the height and width of the curb and gutter, as a division partition; fasten a handle on top and shape the sheet iron the same form as the concrete base of curb and gutter. (See Fig. 14, *C* and *D*.) Place this sheet-iron division every six feet between forms *A* and *B*; tamp concrete all around on both sides of the sheet-iron form, pull out the same immediately after form *F* is removed. Fill in the cuts thus formed with dry sand, mark forms *A* and *B* opposite cuts so as to accurately place the joints thus formed. After each batch of concrete is laid, it should immediately be covered with a top coat of wearing surface.

Cover the concrete base of the curb and gutter immediately, or as soon as possible after the base has been put in place, with one inch of mortar mixed medium wet. Materials used for this mortar and methods of mixing to be as previously described in specifications for Cement Sidewalks.

Slope the gutter to meet the requirements of drainage by increasing the thickness of the top coat on the side nearest the street. Work to an even surface with a straight edge laid parallel with the curb and shifted from form *B* to form *A*. The upper face corner of the curb and angle between the curb and gutter should be rounded with a radius of 1 to 1½ inches. After getting a good surface, float with plasterer's float until a smooth, even surface is obtained. This surface should be wet or very moist. Dust this surface while it is still wet, with granite dust and Portland cement mixed half and half, dusting to take place before the surface water has been absorbed. Immediately smooth down with a trowel. Do not let too great an interval elapse between floating and troweling. Use a curved trowel for top corners of the curb and angles between the curb and gutter. After troweling finish with a soft brush, an ordinary hearth brush or whitewash brush will do. If the top is too dry sprinkle with water. The brush will take out the trowel marks and give an even texture and color to the finished work. Cut the top coat directly over the cuts made in the concrete base, leveling the edges of the cuts with a jointer.

Protection is most important and is fully covered by instructions previously described under head of Sidewalk Paving.

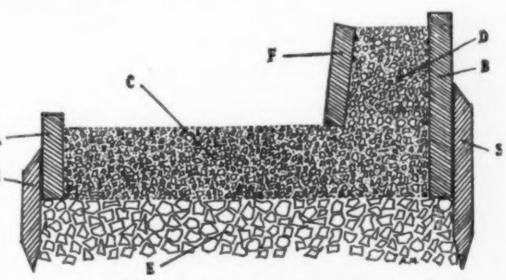


FIG. 14.—CONCRETE CURB AND CUTTER, SHOWING DRAINAGE FOUNDATION AND CONCRETE BASE. (TOP COAT NOT SHOWN)

A—Plank 1½ inch x 6 inches, length as required.
B—Plank 1½ inch x 13 inches, length as required.
C—Concrete base for gutter and under curb.
D—Concrete base for curb.
E—Drainage foundation.
F—Plank 1½ inch x 7 inches, length as required.
S—Stakes nailed to forms *A* and *B*.

A Catskin Carriage Robe

HAVE you ever seen a catskin carriage robe with the skins in their natural colors? If not, you would be as much surprised at its beauty as the writer was, when a young nephew who was visiting me from the country brought his robe out for admiration. It was really beautiful, but it seemed also remarkable as the handiwork of a boy not yet seventeen. He had bagged the cats of all the neighborhood, killed them and tanned the skins. But the lining was still more remarkable. It was of blanket-like material, and this boy had himself taken the wool as it came from the sheep, washed it, dyed it, spun it into yarn, put the yarn on a loom, and had woven it into the cloth, thus alone completing the production of the cloth lining. His father had a small woolen mill driven by a water wheel and covering a floor space of probably 40×60. In these days, when the large factories specialize labor so that different persons perform the different steps in the production of a cloth, it seemed remarkable that the boy should have, single handed, converted the raw material into the beautiful finished article.

A Few Shop Jobs on an Old Car

Hints for the Handy Man with Tools

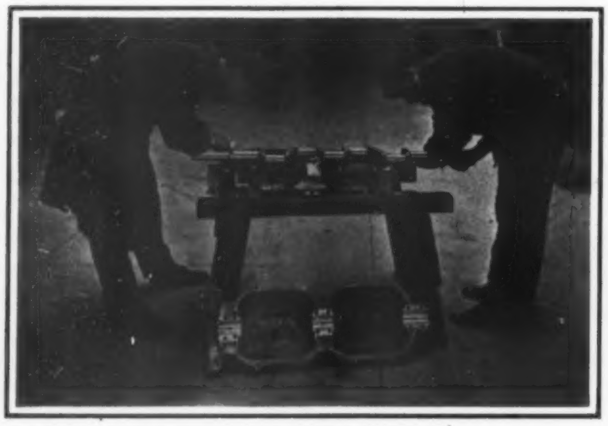
By Herbert L. Towle

Aside from repairing actual breakages, which are not covered in this article, the work of overhauling an old car concerns itself, first, with making good the wear due to use; second, with altering or modernizing certain features, such, for example, as the ignition system, to bring them up to date; and, third, with an intermediate class of repairs necessitated by such things as sagging of the frame or axles, or bends in the steering connections which cause the front wheels to run out of line. In most cases of wear or distortion, the proper remedy suggests itself at once to the experienced shop-man. In many cases, however, the severity of automobile service is such as to reqiure much more careful treatment than would be necessary with other classes of machinery. A few typical instances are noted in the following paragraphs.

MAKING A STEERING GEAR SNUG.

The steering gear is usually the first part of a car to show wear, owing to the violent shocks it must endure, and the necessarily limited sizes of the various bearings. A common fault in old cars is loosening up of the bolts holding the casing at the base of the steering column to the frame. Unless the steering column is well braced to the dash or toe-board, the slightest looseness in these bolts will cause the steering column to shake and the bolt holes to wear large. Tightening up the bolts is but a temporary makeshift. The only permanent remedy is to ream the holes true and fair to the next larger size and put in bolts that are a tapping fit in the holes. It may even be worth while to make special bolts for the purpose from annealed tool steel. A better remedy where it can be applied, is to brace the steering column. This requires that the dash or toe-board itself shall be rigid. A simple method is to make a brass casting to fit the dash or toe-board, having a cored hole a quarter of an inch larger than the steering column. After being put in place, this casting is heated, and babbitt metal is run in to fill the space around the column. If the outside of the column turns, thin paper must be wrapped around it to give clearance, and the babbitt bearing must be 4 or 5 inches long and provided with a grease cup.

In case the steering knuckles are worn loose on their pivot bolts, renewal is easy if the knuckles are bushed. If, however, there are no bushings, the knuckles may be counter-bored and case-hardened bushings driven in. These bushings of course, should be case-hardened inside only, and copper-plated and wrapped with asbestos before baking, to prevent their outer surfaces from absorbing carbon. The same treatment may be applied to the ends of the front cross-link, or the holes may simply be reamed true and pins made and case-hardened to fit them. If new pins are made, they should be provided with oil covers, or, better, small greasecups, and



REPAIRING A CRANK CASE

GROOVING A PISTON

MAKING YOUR OWN AUTOMOBILE REPAIRS

these should feed to the center of the bearing.

LEAK IN RADIATOR.

A radiator may be repaired, if the leak is outside, by emptying it and laying it flat so that the solder will not flow away. To prevent adjacent seams from opening from the heat, they may be kept cool with pads of wet waste.

NEW CRANK-SHAFT BUSHINGS.

Die-cast babbitt metal is now almost the universal material for crank-shaft bushings, and is far preferable to bronze. Quite possibly the crank pins of the engine under consideration are oiled by splash from above, through holes drilled in the upper half of the connecting rod "big ends." If so, the repair man has a good opportunity to prolong the usefulness of the next set of bushings by leaving the upper half entirely plain and feeding the oil from beneath by means of copper or steel scoops sweated into the

ROUNDING UP AN OLD CRANK-SHAFT

bottom caps of the rods. These scoops should be about one-quarter of an inch inside diameter, and shaped to dip squarely into the oil. Short oil grooves should lead crosswise from the oil hole in the center of the bushing, but these grooves should extend no more than half way to the edge of the bushing, so that the oil will not be able to escape from the bearing without doing its part of the work. In handling connecting rods with scoops fitted, care must be taken not to bend the end of the scoop by an accidental blow, as this would defeat the object of the scoop and result in a cut bearing. The reason for leaving the upper half of the bushing plain is that, under pressure, oil squeezes out from a bearing instead of working into it, and grooves in the pressure side would permit the oil to escape at the very moment when it was most needed.

WEAR OF PISTONS AND CYLINDERS.

The piston rings will become leaky before the pistons have ceased to be a fair fit in the cylinders; consequently, replacement of the rings may be the only thing needed. In time, however, the cylinder wears barrel-shaped, and the piston also wears, with the result of oil working up past the pistons in undue quantities, till a noticeable click is produced at each explosion by the side slap of the piston. When this point is reached, the cylinder must be reground and a new piston turned to fit. The clearance between the piston and cylinder should be approximately one-thousandth inch, plus another thousandth for each inch of the piston diameter. That is, a 4-inch piston should have five-thousandths of an inch clearance. The top of the piston should have, when cold, at least double the clearance given elsewhere, on account of the expansion of the piston head when hot.

SAGGED FRAME.

A motor car frame is after all nothing but a spring, and it sags more or less, according to the load. In time the shocks of travel may produce a permanent set in the side members, to compensate for which the motor and gear case should be lined up anew. It is a good plan when doing this to load the frame in some manner to about its normal load. If the sag is small, it can usually be corrected by putting liners under the rear feet of the engine and the front feet of the gear box. Exact alignment is unnecessary if the clutch and gear box are connected by a short shaft having universal joints at both ends. If, however, there is only one universal, or none at all, fairly exact alignment is necessary. An approximate test is had by opening all the compression cocks and turning the crank slowly with the clutch engaged to show whether or not there is binding at any point.

If the frame has sagged so much that liners used as above will not correct the trouble, it is best to apply truss rods underneath the frame. The manner of doing this will depend on the room available for attaching the ends of the truss rods and for placing the two struts. According to the size of the car, the truss rods may be from $\frac{3}{8}$-inch to $\frac{1}{2}$-inch in diameter, and the struts may be from 4 inches to 6 inches high. It is best to attach the ends of the truss rods beyond the spring shackles, and, if possible, over the axles. The struts may be spaced apart about one-third the distance between the ends of the rods. The rivets holding the ends of the rods should be spaced fore and aft and should be about 5-16 of and inch in diameter, two to four being used, according to the size of the rod. A turnbuckle in the center of the rod will draw the frame straight.

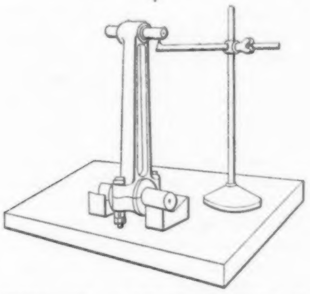
BALL BEARINGS LOOSE IN GEAR CASE.

Annular ball bearings set directly into an aluminium crank case are liable in time to hammer their aluminium seatings until the outer races are distinctly loose. This is avoided in some cars by setting the bearings in bronze cages, thus distributing the contact between the outside of the cage and the aluminium over a larger surface than the outer ball

race itself would afford. In case a ball bearing works loose in aluminium, the best remedy is to counterbore the aluminium about $\frac{1}{8}$-inch larger each side, and machine a flanged bronze ring to fit the aluminium as snugly as possible.

FILLETS ON SQUARE-ENDED SHAFTS.

It is quite common for the shafts in live rear axles of the floating type to engage the differential gears by having square bolts milled on the shaft ends. Quite possibly the outer ends of the shafts may engage driving plates in the wheel hubs in the same manner. If the car has side chain drive, the differential shafts may have their inner ends formed in the same way, and the outer ends may have taper ends with hexagonal flats to hold the sprocket pinions. The best modern practice is either to have the shaft enlarged, so that forming a square or hexagonal of it does not reduce its section below that of the end portions of the shaft, or to forge a disk on the end



TESTING WRIST AND CRANK-PIN BUSHINGS FOR PARALLELISM AFTER SCRAPING THE LATTER

of the shaft with bolt holes or clutch claws on it, the purpose of either construction being to apply the driving force at a greater distance from the center of the shaft. If, however, the shaft is not enlarged, it is very important that the change from the reduced square to full circular section be gradual, not abrupt. An abrupt shoulder at this point concentrates the fiber stress, and results in the shaft eventually breaking under strains which it would have easily endured if large fillets were provided instead of a square shoulder. The same thing applies to hexagonal ends. If the shaft is taken out in the course of overhauling, fillets can easily be put in by means of an emery wheel.

WELDING CRACKS IN ALUMINIUM CASTINGS.

Until recently, it was necessary either to discard a cast aluminium part belonging to the crank case or gear case, in the event of its being cracked, or to rivet a more or less unsightly patch over the crack to close and strengthen it. Nowadays such work is done by oxy-acetylene welding. The process, of course, cannot be described here, but it consists essentially in chipping a triangular groove of the width and depth of the crack, and filling this groove with molten aluminium, flowed into it under the heat of the oxy-acetylene blow-pipe flame. The same process is applicable to repairing cracked water jackets and occasionally cylinders, as well as repairing damage of various sorts to wrought iron and steel. Portable apparatus for this purpose may be had in the market, and should be a part of the equipment of every first-class automobile repair shop.

REFITTING THE DIFFERENTIAL.

The hardest part of the differential to lubricate, and the likeliest, therefore, to wear out soon, is the "spider," on which the four small bevel pinions are carried. The spider is usually case-hardened; the pinions may or may not be bushed. Holes are usually drilled in the pinions, through which oil is worked by the rolling of the teeth. If, however, the user makes the mistake of using grease to lubricate his differential, the repairer is likely to find that the bushings of the small pinions have been cut to pieces, owing to the grease refusing to enter. The journal portions of the spider are also likely to have suffered. If the pinions are bushed, the user is fortunate, for new bushings are easily purchased; and, even if the spider must be ground to true it up, special bushings to fit the new diameter of the spider will not be expensive. If, however, there are no bushings, both pinions and spider must be replaced.

RERIVETING AN OLD FRAME.

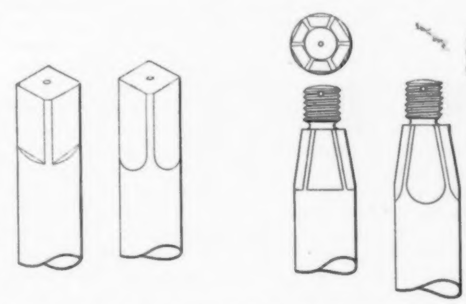
Most of the frames made to-day are as strong in the riveted joints as elsewhere. Occasionally, however, one may find a frame which through long service has loosened up its joints and must be reriveted to make it sound. This involves dismantling the entire car and taking the frame close to a forge, as the riveting must be done hot to be secure. Before riveting, the holes should be reamed to make sure that they line up evenly and are the proper size for the rivets selected. The frame members must be carefully cleaned after the old rivets have been cut out, as dirt between the surfaces will spoil the tightness of the job.

TAKING UP PLAY IN SPARK AND THROTTLE CONNECTIONS.

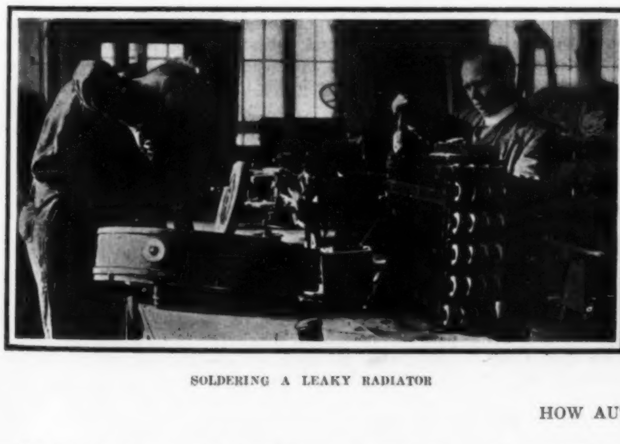
In few cars are the spark and throttle connections so carefully made that they don't work loose after the car has run a few thousand miles. When that point is reached, either the operator must depend on guesswork and knack when running slowly, or springs must be attached to take up the slack and exert constant pressure in one direction. The latter expedient is simple and in most cases sufficient. However, a first-class job can be done at small expense by purchasing the ball-jointed rod-ends manufactured for this purpose and sold to the trade. These ends are usually made to screw over 3-16-inch rods, or to screw into tubing of the same inside diameter; being of the ball joint type, they are flexible in any direction.

OVERHAULING THE IGNITION SYSTEM.

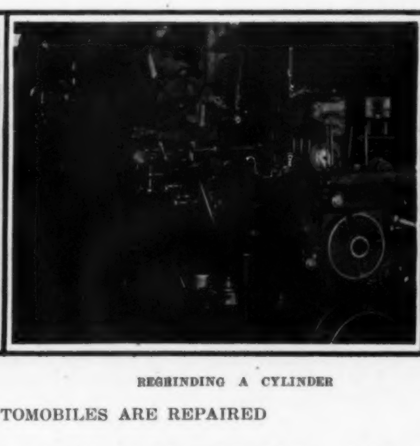
The winter is the proper time for making any changes which may be desired in the ignition system. The number of reputable high-tension magnetos at present available to the user is sufficient to afford little excuse for disappointment in this important item of equipment. If the price of a high-tension magneto is an obstacle, the user can purchase at a reasonable figure a battery system of high-current economy and great reliability, which produces a single spark for each ignition and requires only common dry cells as a source of current.



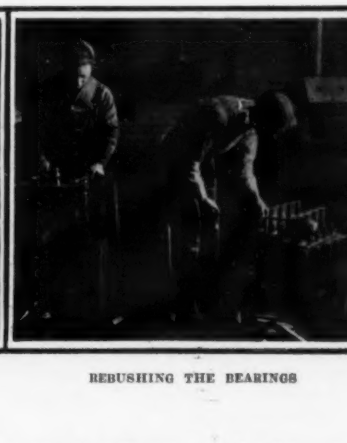
BAD AND GOOD SQUARE AND HEXAGON ENDS OF SHAFTS



SOLDERING A LEAKY RADIATOR



REGRINDING A CYLINDER



REBUSHING THE BEARINGS

HOW AUTOMOBILES ARE REPAIRED

The Outlook for the Future of Zinc Production

IN making a forecast of the probable future development in the industries of the most important metals, Prof. J. A. Kemp takes up among others the case of zinc, with regard to which he says:

Zinc is a metal of comparatively late introduction into commerce in the large way. Although known for centuries, it has found its chief applications in the last sixty years. There was no zinc mine in the United States until approximately the year 1850, and from the Missouri region whence we now obtain our chief supplies, the really serious contributions began about 1870. Lead, indeed, was mined and prized long before this, but the associated zinc ore was thrown one side on the dumps. In the west the same experience continued until much later. Zinc was a nuisance in the metallurgical treatment of lead, and even the lead was sought and smelted either because of its own silver contents or because it made possible the treatment of other refractory silver ores. In the metallurgical work the zinc was volatilized or slagged off and was lost. Indeed, one of our most serious metallurgical problems has been the successful treatment of lead-zinc ores, and many investigators have addressed themselves to its solution. Now that anxiety is beginning to manifest itself regarding zinc supplies for the future, the desire to save it is stronger than ever.

"Zinc, however, is a peculiar metal and because of the exigencies of its treatment its ores must possess greater richness and greater purity than those of other base metals. Thus in the case of copper a ten per cent ore is in later days phenomenally rich, and as it can be smelted in a shaft furnace the presence of iron or lime or other bases that make fusible slags is an advantage. But zinc ores, perhaps after preliminary roasting, must be reduced and the metal must be volatilized at a high temperature from a small charge in a retort. The presence of fusible bases destroys the retort and the bases are therefore debarred beyond certain small percentages. Thus it happens that a forty or fifty per cent zinc ore might be valuless if contaminated by iron or lime beyond a narrow margin. While almost any conceivable mineralogical aggregate that contained ten per cent of copper would be a very valuable ore, a zinc-bearing aggregate with four or five times as much zinc might be unsalable.

"In 1907 the United States was the chief producer of zinc among the nations, but, as a rule, Germany leads, followed by this country and Belgium in the order named. In late years our output has varied from 26 to 30 per cent of the total. As a rule Germany is 2 to 4 per cent in excess of us and Belgium is 4 to 5 per cent less.

In America, Missouri is the chief source of zinc. Its production from the mines was in 1908 approximately one-half the output of the entire United States. New Jersey follows with somewhat over one-quarter the total, while all the rest are much smaller.

"The Missouri ores as thus far produced have been obtained from comparatively shallow depths. They extend lengthwise and sometimes laterally to greater dimensions than vertically. While it is not beyond the possibilities that lower lying deposits may be discovered, since zinc ores are found in Arkansas in strata of lower geological position, anticipations of this reserve have not as yet been demonstrated on a large scale.

"In New Jersey the future is best forecast of all. For thirty or forty years there is no occasion of anxiety. Yet thirty or forty years pass quickly and then we must prepare to look for other sources. To make the zinc blende of the Rocky Mountain region available, an increase in price is practically necessary, otherwise the metal can not stand the freight charges. There is zinc ore in the west, but to what extent we cannot well say. It has been avoided rather than sought in most of our mines. Yet we do note symptoms of attention to it. In Butte, Montana, efforts are being made to concentrate it. Shipments of oxidized ores have been made from New Mexico for some years past. Until recently large amounts of peculiar appearance seem to have been overlooked at Leadville, Colorado. They promise to be an important resource. A government commission has reported upon the occurrence of the metal in British Columbia in the hopes of utilizing the ores. From Mexico, too, we learn of explorations for zinc. Conditions are changing in the case of this metal,

and more and more of it is certain to be brought from remoter localities. But when we look a long way ahead, say for a century, we cannot feel free from anxiety. The condition of mind is even more prominent in Europe than in America. The waning of the famous old mines near Aix la Chappelle, and the apprehensions felt regarding other sources, have lead to a world-wide search. Zinc ores, for example, now reach Hamburg from the Pacific shore of Siberia, and as other discoveries are made, additional points remote from present smelting centers are likely to be shippers, provided that transportation is by water. Nevertheless, all these new conditions call for advances in price, and before many years zinc bids fair to take the upward course."

Modern Scientific Research*

Its Object and Methods

By Sir William A. Tilden, F.R.S.

RESEARCH is a word much used in newspapers and in public discussions nowadays, but few people outside purely scientific circles have any clear idea as to its meaning. Of course, the dictionary tells us that it signifies a searching again or a careful search, but the question then arises, What is the object of the search and are there any rules to guide?

The object may be purely visionary, as was the object of the early chemists and alchemists, whose operations, extending through the dark centuries of the Middle Ages, left behind practically nothing but an extensive, though barren, literature, the witness of the credulity and ignorance of those times. The lesson to be derived from the whole of this strange history is one which needs to be continually revived and set in the new light of modern discovery and invention. The lesson is simply that until men began to observe and interrogate nature for the sake of learning her ways, and without concentrating their attention on the expectations of useful applications of such knowledge, little or no progress was made. In other words, until a sufficient foundation of pure science has been successfully laid there can be no applied science. Real progress comes from the pursuit of knowledge for its own sake.

I say, again, this truth needs to be continually reiterated, for there are still too many people who think that the true and only business of science is to find out useful things, and who regard all the rest as waste of time.

The first qualification for research is undoubtedly that kind of inspired curiosity which can never be eradicated, and which we know by many examples is not defeated by such obstacles as poverty, or ill health, or pressure of other necessary occupations. Another qualification is some knowledge of the subject chosen for inquiry. As to this latter qualification considerable differences of opinion have been expressed. Priestley, whose statue stands near the Town Hall in Birmingham, and many of the chemists of his time, had very little preparatory instruction, but some of them made discoveries of fundamental importance. Priestley seems to have been of opinion that very little preparation is necessary, and the discoveries which might result from experiment were regarded by him as largely the result of chance and to be compared with the game which might fall to the gun of a sportsman in a new country, and whether fur or feather cannot be foretold. But though this might have been partly true in Priestley's time, it is certainly very far from true in our day, when the accumulation of knowledge, however imperfect, is still immense.

Every great discovery is the culmination of a long series of discoveries, each of which is a necessary step, and ignorance of these preliminaries stands in the way of advance.

It will be worth while to examine a few cases by way of illustration. No better example can be found than the establishment of the great principle in chemistry commonly called the periodic law. According to this law, the properties of the elements and of their compounds stand in a definite relation to their atomic weights.

Modern views concerning the constitution of gases afford another illustration of the way in which the possession of one kind of knowledge leads to more knowledge. Forty years ago students were led to believe that there were two kinds of gases, namely, on the one hand, those which by the action of cold, or pressure, or both together could be liquefied, and on the other hand some half dozen which could not be reduced to the liquid state. This was attributed to some fundamental difference of constitution in the two kinds of gas.

If we look for an example drawn from the domain of biology there is the doctrine of evolution, now universally accepted, which is based on the results of the patient collection of facts by Darwin and Wallace. But those facts would perhaps not have been collected and they would certainly have been without meaning, but for the results of the study of comparative anatomy by previous generations of naturalists and palæontologists, as well as the recognition of the great doctrine of uniformitarianism in geology proclaimed and established by Lyell.

The examples cited will not appeal to the practical man in the same way as some instance taken from a direct application of science to business or practical affairs. If it is really necessary to consider a case of that sort, nothing could be better than the *dynamo*, which, as a transformer of energy, comes into prominent daily use in connection with lighting, traction, and as a general motive agent. The detailed history of the evolution of the dynamo would be a long story, and on this occasion it is only necessary to point out one or two facts. For the fundamental principles involved we must go back to Benjamin Franklin, and Galvani and Volta, all in the eighteenth century, and later to 1831, when Faraday discovered the generation of induced currents by moving a conductor in a magnetic field. But doubtless the experiments made by Franklin with the kite, by Galvani on frogs' legs, and by Volta and Faraday with bits of wire, were by the people of their day looked upon with a mixture of amusement and contempt, just as some people even at the present time are apt to exclaim, "Who cares whether there is oxygen in the sun?"

It is obvious, then, that whatever may have been possible in Priestley's time, the wholly unrestricted person cannot expect to meet with much success in these days in the discovery of new facts; and although the exceptional man may acquire in a very short time some knowledge of a special part of a subject, he is in perpetual danger of falling into great mistakes. It seems to me that a considerable amount of knowledge, skill, and experience is an indispensable equipment for anyone who enters seriously into the practice of scientific research. Not that these qualifications alone serve as inducements to such a career, for it would be quite easy to point to examples of learned people who have added nothing new to the branch of knowledge with which they are best acquainted. This is not necessarily due to indolence, nor to ignorance of the methods of research, but is merely the result of peculiarity of temperament which lacks that divine curiosity which alone supplies the stimulus.

I am speaking now only of real scientific research, the inquiry into the secrets of nature, not of the occupation of those who have only practical ends in view.

Looking back over the great principles of natural science, we see that in every case they have been established by the efforts of the amateur, and by amateur I mean all who have undertaken the work for the pure love of it. This includes, not only men of independent position like Cavendish, Lyell, and Darwin, but a large number of men who have held the office of professor or teacher, but who, in this country at any rate, are neither paid to do such work nor required by the conditions of their appointments to undertake it. So far as I know, there is but one institution in this country in which the professors are not required to teach, but only to press forward into the unknown, and that is the Royal Institution in London. But the character which that famous place has assumed during the last hundred years is not that with which it began its career. It was started at the end of the eighteenth century by Count Rumford with purely utilitarian purposes in view, namely, for teaching the applications of new discoveries in science to the improvement of arts and manufactures and to "facilitating the means of procuring the comforts and conveniences of life"; and while retaining that character and those pretensions it soon came to the verge of collapse. But Davy's lectures and discoveries changed all that, and Faraday's genius consecrated the laboratories for all time to the service of pure science.

Let us review very briefly the great principles on which physical science is based.

First, of course, there are the fundamental principles of the conservation of matter and of energy, the latter finally established on a quantitative basis by Joule in 1843. There is the principle of uniformitarianism introduced into geology by Lyell now extended so as to include, not only the phenomena of this earth, but of the whole cosmos, such extension being mainly due to the use of the spectroscope by Kirschoff and Bunsen, and only a little later by Huggins. The principle embodies in the so-called periodic law of the elements, already referred to, has led to a general belief in the evolution of matter from one primary material, and physicists and chemists are vying with each other in the endeavor to gain evidence as to the details of the process. I need scarcely say that the principle of evolution as applied to living beings is associated indissolubly with the names of Darwin and Wallace.

Notwithstanding the discovery of radium and its allies, and the discoveries by J. J. Thomson as to the disintegration of atoms into corpuscles a thousand or more times smaller, all ordinary chemistry is built up on the conception of atoms introduced by John Dalton just a hundred years ago. The consolidation of this theory has proceeded as a consequence of the discoveries begun in 1872 by Wislicenus, developed by van't Hoff and Le Bel in 1874, and confirmed by an army of other workers down to the present day. We now not only suppose it probable that atoms are placed within a molecule in definite positions relatively to one another, but in a great many cases their order and arrangement in space can be positively traced.

Suppose all these great laws and principles never to have been discovered—science and its applications would not exist, and the world would have remained in about the same condition as it was in two hundred years ago. Railways, electric light and traction, telegraphs, dyes, explosives, antiseptics, anæsthetics and many other drugs, metals such as sodium, aluminium, magnesium, tantalum, and even modern steel would be unknown.

But these things are merely the results of the recognition, development, and application of the principles already indicated as fundamental, and the immediate corollaries from them. And so it seems that there are two fields for research which are equally necessary to civilization and progress. In the one the worker watches the operations of nature and puts questions in the form of experiments solely with the desire to find out her ways; in the other attention is given only to those laws, facts, and phenomena which can be made serviceable to man. There is much more public anxiety in regard to the last, and considering how entirely ignorant are most people about the principles of physical and natural science this is not greatly to be wondered at.

Some people are under the impression that there is an art of scientific discovery which can be communicated from one person to another. That is not my belief. I think the history of scientific discovery shows that each successful pioneer has invented methods for himself, or has at least known how to select from the tools ready to his hand. And with regard to personal qualifications, I do not think it possible to create that combination of mental powers which is called insight. Hence I have very grave doubts about the advisability of spending time and energy in trying to evoke and cultivate the capacity for research in all students in colleges and universities. If this were possible we ought to see greater results in those cases in which it has already been tried. The judicious teacher will, of course, be careful to avoid any appearance of indifference toward ardor and enthusiasm whenever they appear, and he should ever be on the lookout for indications of the kind of capacity which alone repays cultivation, and give it all the encouragement in his power. But the clamor which has of late been raised as to the supposed desirability of extending instruction in the principles and methods of research, down to the very beginners, indicates, to my mind, a lack of judgment on the part of some of the agitators. It seems to be forgotten that in every branch of experimental science, and especially of applied science, there is a great deal to learn, and it is necessary that at the end of his career as a student a young man should be able to *do* things practically and usefully. The theory of music and the laws of harmony are very desirable for the musician, but if he is to be a performer he must devote the greater part of his time to practice on his instrument, whether piano or violin. The case of the student of science is analogous, and if he does not devote a good deal of time to learning the technic of his business he will not be ready for research or anything else. At the present time too many students who can write at length on theoretical questions of a most recondite character, and who boast that they have been engaged in research under eminent teachers, are yet incapable of choosing a subject for

* Presidential address delivered to the Vesey Club, Sutton Coldfield, England.

themselves or of handling successfully a subject found for them by their teachers or someone else.

With the object of testing the influence exercised by methods of education in science on the development of the faculty of research, I have lately had the curiosity to compare the results indicated by the lists of doctors of science of the University of London. Up to 1886 this degree was awarded on the results of a very severe examination. From 1887 onwards it has been obtainable only on the production of a thesis supposed to embody the ideas and the work of the candidate on some subject selected by himself. The examiners are at liberty to impose an examination with the object of assuring themselves of the candidate's knowledge of his subject, but as a matter of practice the examination has been reduced to a mere formality. It was expected that this change of system would be followed by indications of much greater fertility in the fields of research. Owing to the completeness with which chemical literature is indexed, I have been able to make a comparison between the number and character of original papers published by the chemists in these two lists within the ten years following graduation in each case. I have not been able to make so strict a comparison among the physicists owing to the distribution of their work through so many media of publication, but I have been led by a careful survey to the same conclusions, as in the case of chemists. In both classes, the *Examinees* and the *Researchers*, if they may be so distinguished, there are cases in which the doctor, after taking his degree, has done no original work—or at any rate none that was fit for publication—and his name does not appear in the literature of his science. On the other hand both lists contain famous names. I will only mention in passing that the names of Larmor and Lodge appear among the examined. On the whole, I see no indications that the procedure by thesis has had any effect whatever on the character of the graduates. If anything, the list of examined is of somewhat higher quality than the list of graduates by dissertation, for there are nine out of fifty-four who have become Fellows of the Royal Society, while among the others there are only eight out of fifty-nine who can write themselves F.R.S.

In the latter list there may be one or two who may achieve this distinction hereafter, but there are no indications that in the long run the amount and quality of the contributions made to science by the graduates who are supposed to have been trained to research will surpass those of the men who had to face the ordeal of examination.

Does this not seem to justify my original contention that the researcher is born, not a product of educational manufacture, and that his disposition to research will survive all sorts of adverse conditions, including those which are by some people supposed to be inherent in examination?

I feel convinced that most of the great discoveries of the future will be made, as in the past, by the inspired amateur, working usually alone and often on apparently insignificant beginnings, and with results which may not at first receive any attention from the world.

It is, however, necessary in these days to provide for some form of co-operation in research, partly for the reason that the cost of some kinds of investigation is quite beyond the means of most private persons, and partly because of the unfortunate separation which still prevails, chiefly in this country, between science and industry.

First, then, science may justly look for assistance from the State. In England this is given in a grudging way. Parliament allots £4,000 to the whole range of the physical and natural sciences. The fund is administered by the Royal Society, and the biggest slices out of it are taken in the form of contributions to the expenses of expeditions. Then there is the National Physical Laboratory, with an expenditure of about £25,000 a year, of which £7,000 comes from the treasury. This seems to be all that comes directly from the National purse; but science is endowed to a certain extent by her friends. This assistance is represented by the equipment of certain schools and colleges by the Guilds of London, and by the small research funds of the Chemical Society and the British Association.

Something more systematic is, however, wanted, and I feel strongly that some of the rather large funds given in the form of scholarships to young students could be more advantageously used if applied to the maintenance of proved investigators to make them independent of the necessity to earn a living by teaching or other professional work. I recognize, however, the difficulties which would attend any such scheme. In the first place, discoveries cannot be made to order. An able, industrious, and conscientious man might work for many years without producing definite results, and a few cases of that kind would destroy or shake public confidence. It would also be necessary to provide incomes large enough to retain the services of the most able men.

With regard to the application of science to industry, I think our manufacturers have made some progress during the last thirty years. But they still suffer from delusions. The mistake most commonly made arises out of a misapprehension of the methods, powers, and promises of science. It still seems to be too often supposed that a scientific man, called into hurried consultation, can at once overcome a difficulty in a manufacturing process or can devise an improvement which, if adopted, would represent many thousands of pounds profit to someone. If this were so scientific men would be better off than they usually are. What is wanted is a general recognition of the principle that improvements can be expected only as the result of the use of scientific methods, which are simply the methods of reason applied to the materials provided by experience.

What every manufacturer wants is to begin with a scientific education, if not for himself then for his sons or successors, so that those who are at the head of affairs may understand fully the problems before them and in what direction to look for help towards improvement. Failing this he will be dependent on the services of paid assistants, and those services cannot be expected to produce the desired results unless they are paid for on a liberal scale. In this country there has not hitherto been sufficient attraction to draw into the field of technology a due share of the best brains of the nation. The prospect of ultimately reaching a salary of two or three hundred a year at the utmost is not sufficient to induce a young man of first-rate ability to spend several years of his life and a thousand pounds or so of capital in scientific and technical studies; and so the supply of the highest class of scientific assistance is at present far from what it ought to be.

But suppose conditions to improve, a question arises as to the best way of turning such assistance to account.

A suggestion has lately been made that a new society should be formed, to be constituted of trade committees associated with experts in various divisions of science, to carry on experiments confidently in the interests of the manufacturers who become members of the society. It seems to me that any suggestion is better than none if it results in the closer association of industry and science; but I think this particular proposal would not be found to work in practice. The requirements of different industries are too numerous and complicated to be met by an arrangement so simple, for each committee would find itself occupied with so many different problems that nothing would be accomplished, unless, indeed, the staff were very large. In my judgment each manufacturer must endeavor to work out his own salvation. Moreover, the experience of the German manufacturer, and to some extent also of the American, shows that it can be done effectively. The most famous example known to me is the case of the great Badische color works at Ludwigshafen, on the Rhine. There is a factory which employs some 5,000 men, and which pays, and has always paid, 25 to 30 per cent or more on its ordinary capital. The great feature of its organization is to be seen in the direct association of manufacture with research conducted by a staff of highly skilled scientific men.

In England arrangements so complete are unknown, and the number of highly qualified chemists and physicists employed in works is very small. I say nothing about engineers, with whom I am not so well acquainted, but the greater number of the chemists are merely testers doing routine work, and because such men, receiving the wages of a clerk, have not been able to advance the industries with which they are connected, their employers have in too many cases in the past come to the conclusion that science is of no use. In the meantime many things have happened. The neglect of organic chemistry in England forty years ago led to the complete removal of the coal-tar dye industry to Germany, where since that time has sprung up the equally important manufacture of synthetic drugs. The saccharin, the antipyrin, the artificial perfumes consumed in England are not made here, and it now looks as if the fixation of atmospheric nitrogen in the form of nitrate, so important from the agricultural and industrial points of view, was going to be taken possession of by Germany and America acting together, England being left out.

Such things have been said over and over again for the last thirty years or more, and I am not aware that such statements have been shown to be fundamentally mistaken, nor has there ever been any public explanation of the indifference displayed.

The link between science and industry must be established by the masters of industry themselves. I do not believe in the efficacy of much of the technical instruction which is talked about, and I fear that much money is being wasted in the attempt to imitate industrial operations in schools and colleges. What is wanted is the highest and most complete kind of instruction in pure science, following a good general education conducted on such lines that the fittest only are passed forward to the university or scientific school. Young people educated in this way form the material which should be utilized by the manufacturer. But he must not expect that a man so prepared is going to earn his salary the first year or two. He has got to learn his business, and must have facilities for doing this, or such talent as he has cannot be turned to account, and this can only be done by taking him into the works. This is a subject on which a great deal might and should be said, but such a discussion is not suited to the present occasion.

In conclusion, I may perhaps be allowed to give a few minutes to a glance at the future—not that I can pretend to descry very much.

We must remember that there is no finality in physical science. The farther we go the wider does the horizon before us become, but every discovery of a new fact or principle gives us a new instrument to help on to higher things. Hence we may reasonably suppose that, wonderful as the past has been, the future will be more wonderful still.

Here I will venture to draw a distinction between invention and discovery, and to invention there is probably no limit. It may be said to consist in making new combinations and permutations in the elements of knowledge already acquired. Among the inventions which have affected the condition of mankind, those which are concerned in locomotion stand first. It may truly be said that life is lengthened, not only by years, but by opportunities, and from this point of view quick traveling, provided by steam and electricity, is a great advantage. It would be unwise to utter any predictions as to what may hereafter be done with big ships and aeroplanes, only the old-fashioned type of nervous system—already shrinking from the increased noise and bustle of the town—shudders at the thought that neither distant valley nor mountain top, from the tropic to the pole, can now be expected to provide an asylum where peace secure from intrusion is to be found.

In Samuel Butler's "Erewhon," a remarkable book published about forty years ago, a country was pictured in which moral delinquency was treated with sympathy and condolence, while bodily disease of all kinds was held to be a crime, and was punished by fine or imprisonment. I suppose it will take a good many generations to reach that condition of enlightenment, but the time cannot be far off when the propagation of infectious disease will in all civilized countries be abolished.

The habitability of the planet Mars has of late been a subject of much revived discussion. The possibility or probability of the existence of intelligent beings in other parts of the universe, long a subject of debate, is a question of profound interest, but whether communication with them from the earth can ever be established, who can tell?

But as to discovery in physical science, as already said, the horizon widens as we go on; but it seems not improbable that there is a limit set, though as yet very far off, by the capacity of the human intellect. Nature's ways used to be thought simple, but now we know that she is not only mysterious, but complex. However, there is every reason to expect that great strides are possible, even in the immediate future. The sort of problems which remain to be solved are represented by such questions as the following: What is the cause and nature of gravitation and other sorts of attraction? What is the difference between positive and negative electricity, and what is the relation of electricity to matter? What is the nature of chemical affinity, and is it really electrical? What is the constitution of the elements, and is the transmutation of metals a dream or a physical possibility?

The penetration into final causes seems as we proceed to be further and further out of our reach. The problems of life and mind are, up to the present, inaccessible to man in his present state, and, notwithstanding the hopes and beliefs of some physiologists it is safe to say that they will remain so for a long time to come, if not always.

And even in regard to common matter and the physical forces, all we know about them is derived from the perception of phenomena through the agency of our senses. Now the senses, sight, hearing, and the rest, have been evolved, not to provide the means of surveying nature, but for the protection and advantage of the body to which they belong. It is possible, therefore, that the human view of phenomena is only a partial and imperfect view; at any rate, the world which is open to the sense perception of a man must be very different from that which is perceived by many animals with their highly specialized senses, such as the scent of the dog, the sight of the carrier pigeon, and perhaps other senses for which we have no name.

"In its ultimate nature," said Herbert Spencer, "matter is as absolutely incomprehensible as space and time. Whatever supposition we frame leaves us nothing but a choice between opposite absurdities."

The World's Daily Weather Maps

Systems Used in Various Countries

If you should wish to know just what the weather was doing on a particular morning at a particular spot on the land surface of the globe, the chances are about two in five that you could satisfy your curiosity by visiting a meteorological library and consulting its files of daily weather maps.

The accompanying diagram (Fig. 1) shows approximately the area of the earth's surface that these maps now cover. Nearly every civilized country, including the larger European colonies, now publishes at least one daily weather map, based on telegraphic reports. A few countries publish several maps, *i. e.*, maps are issued at several points within their respective territories. Thus (including maps published in the daily newspapers) the United States Weather Bureau issues daily maps at about one hundred places in this country. Germany publishes about twenty maps, the most important of which is that issued at the Deutsche Seewarte, in Hamburg. India publishes three maps. Most countries, however, issue a map at one place only: viz., the headquarters of the national weather service.

The area represented by the map is not, in most cases, limited to a single country. This is notably true in the case of the European maps, the majority of which cover the whole of Europe. The Egyptian map includes stations in Italy, Greece, Tripoli, etc. The maps of the United States Weather Bureau overlap with those of Canada.

In point of workmanship, the lithographic map published daily at Washington stands unrivaled, while the handsome maps issued by Japan and Argentina compete for second place. It would be invidious to specify the publications standing at the other end of the scale. Suffice it to say that several extremely crude productions of this sort are issued abroad; but in these cases the wonder is that they are issued at all, considering the very meager funds and limited staffs the meteorological services in question have at their command.

Besides the maps based on telegraphic reports, and issued a few hours after the observations that they collate are taken, there are several highly interesting synoptic maps the data for which are collected by a slower method, and which generally appear months, or even years, after the date to which they refer. The most notable publication of this character was a daily chart of the Northern Hemisphere, published from 1877 to 1887 by the United States Signal Service—the predecessor of the Weather Bureau. Several series of maps have been published for the North Atlantic Ocean and the adjacent continental areas, and two of these still appear, viz., the "Cartes Synoptiques Journalières," begun by Hoffmeyer in 1873, and now issued jointly by the Deutsche Seewarte and the Danish Meteorological Institute, and the "Internationaler Dekadenbericht," published by the Deutsche Seewarte. These maps of the ocean are based on the meteorological logs of vessels, as well as the reports of land stations. A specimen map from the "Dekadenbericht" is shown in Fig. 2. This publication presents a somewhat sketchy picture of the weather over a wide area of land and water, and appears with remarkable promptitude; *i. e.*, only a few weeks after the period to which it refers.

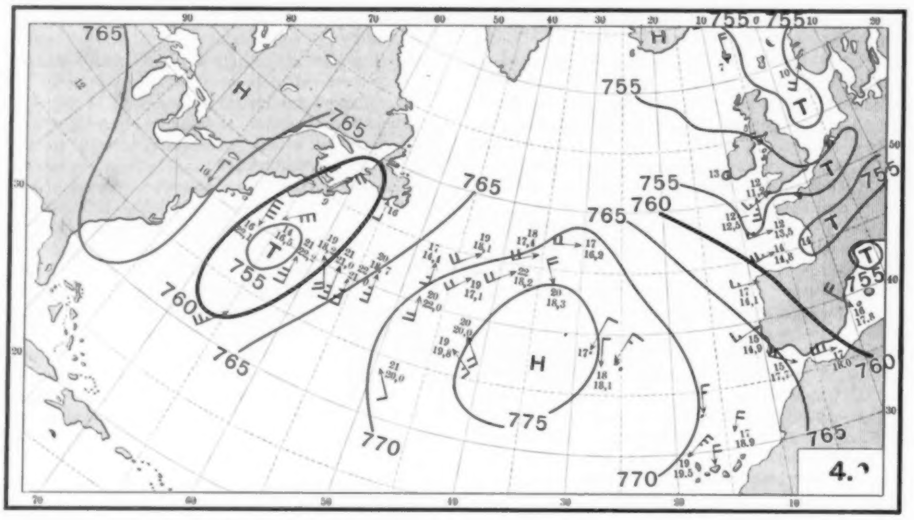


Fig. 2.—WEATHER MAP OF JUNE 4th, 1910, 8 A. M.

The point of the arrow shows where the observation was taken. The arrow flies with the wind. The tails of the arrow show the force of the wind on the half-Beaufort scale. The air temperature is shown in whole degrees (Centigrade), water temperature to tenths of a degree. The curved lines are isobars, or lines of equal barometric pressure. Areas of high pressure are marked "H" (*hoch*); of low pressure "T" (*tief*). (From the "Internationaler Dekadenbericht.")

The ordinary daily weather maps, although primarily devoted to the weather prevailing over the land, tend to spread out more and more over the adjacent oceans. This expansion is made possible by the utilization of reports from islands—such as Iceland and the Azores—and, to a limited extent, of wireless reports from ships. Observations of the latter class (*i. e.*, wireless reports) are regularly shown on the English daily weather map, but, it must be admitted, do not as yet add much to the value of the publication.

In contrast to the European maps, those published in the United States are based on strictly simultaneous observations. They show the weather prevailing all over the country at 8 a. m., Eastern Time. In Europe the telegraphic observations are made partly on standard time and partly on local time, and the hour of observation thus fails to coincide by two hours and more, in extreme cases. However, in Western Europe, including the British Isles, the observations are nearly synchronous.

The problem of collecting the observations promptly enough for use on the charts, and in forecasting, has been a difficult one in all countries. It is solved most successfully in the United States, where the Weather Bureau is given priority by the telegraph companies at the time its reports are being despatched, and where the process is further facilitated by the use of an ingenious "circuit" system, *i. e.*, the observations are assembled at a few points, and at the same time are copied off at each station on a circuit as they pass over the wire; this means a wonderfully rapid interchange of observations among the stations, and enables the Bureau to publish its map simultaneously at many points throughout the United States. In Europe national boundary-lines—and the indisposition of the authorities in charge of the telegraph systems, which are generally operated by the government, to give special consideration to meteorological business—are serious obstacles to rapid transmission. In all countries the reports are sent in cipher. A uniform code is used for this purpose in Europe.

The history of daily telegraphic weather maps extends back about sixty years. A few tentative undertakings of this kind were carried out both in Europe and America about 1850, but the first map that was destined to be a permanent enterprise was the French "Bulletin Internationale," begun by Leverrier in 1863, and this has continued without interruption to the present day. The continuous series of United States weather maps began with Professor Abbe's maps, issued at Cincinnati in 1870, and soon after taken over by the Signal Service in Washington.

The first published daily weather maps of the British Meteorological Office began in 1872.

Fig. 1.—LAND AREAS EMBRACED IN THE DAILY WEATHER MAPS OF THE WORLD

Within a few hours after the time of observation, weather maps, based on telegraphic reports, are published for the regions indicated by the shaded areas.

Proposed Department or Bureau of Public Health

The Secretary of Agriculture, while in hearty accord with the general proposition to provide better facilities for work in the interest of the public health, expresses himself as opposed to any plan which will remove from the Department of Agriculture the inspection work involved in the enforcement of the food and drugs act and the meat-inspection law, to say nothing of certain plans which would take away the biological and entomological work of the Department. "To remove from the Department of Agriculture the meat inspection and veterinary work," says the Secretary, "would, I believe, be a great detriment to the work of this department and to the agricultural and live stock interests, without any corresponding gain in efficiency or advantage to the public, and would result in increased expenditures rather than in economy. For example, the field work for the eradication of diseases of animals is carried on mostly during the summer, while the work of slaughterhouses is heaviest during the winter; and it is thus found to be practicable and economical to shift men from one to another of these branches as the needs of the service require." The Secretary thinks it would be an expensive mistake to take away from the Department of Agriculture work which it is performing satisfactorily, and which it can perform better and more economically than any other agency.

New Physical Apparatus*

Simple Instruments for the Laboratory

A VACUUM TUBE OSCILLOSCOPE.

GEHRKE has shown that in a vacuum tube containing nitrogen the negative glow occupies a space exactly proportional to the strength of the electric current which produces it. Desselhorst has found that this luminosity is practically instantaneous, its beginning and ending coinciding exactly with the closing and opening of the circuit. The Berlin firm of Boas has constructed a vacuum tube oscilloscope which is very well adapted for the observation of the phenomena of currents of high frequency. The arrangement of apparatus is indicated in the first diagram (Fig. 1). *A* represents the primary oscillatory circuit, in which the capacity is furnished by the Leyden jar C_1, and the self-induction by the interchangeable coil P_1. A spark-ing coil can be bridged over the gap *F*. The secondary circuit, shown at *B*, contains a variable capacity C_2 and an interchangeable inductance coil P_2. The secondary circuit is influenced more or less powerfully by the primary circuit, according to the distance between the coils P_1 and P_2. The character of the oscillation in either circuit can be studied by means

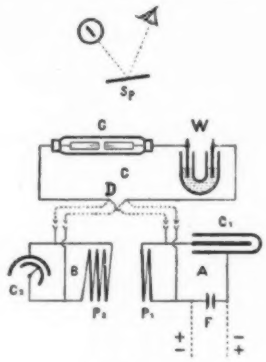


FIG. 1

of the apparatus *C*, which contains the vacuum tube *G*, and which is bridged across either of the coils P_1 and P_2 by means of the high-tension commutator *D*. A water resistance *W* is connected in series with the vacuum tube, in order to reduce the consumption of current. The tube *G* is observed by means of a two-faced mirror *Sp*, which is rotated by an electric motor at a speed which may attain 7,800 revolutions per minute. The observer sees in the rotating mirror two undulating lines of light, the form of which corresponds exactly to the momentary periodicity and general character of the electric current.

THE THEORY OF GRATING INVERSION.

It appears from the experiments of Hertz that a grating formed of parallel wires is most transparent for electromagnetic waves when it is in the position shown at *A* in the second diagram (Fig. 2), with the wires perpendicular to the electrical vector *E* of the waves, and parallel to the magnetic vector *M*. This phenomenon is known as the Hertz effect.

On the other hand, the researches of Du Bois and Rubens appears to prove that a fine wire grating is most transparent for very short waves, that is, the waves of the visible spectrum, when it is in the position *B*, with the wires parallel to the electric and perpendicular to the magnetic vector. This phenomenon is called the Du Bois effect.

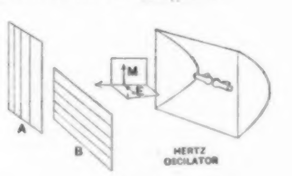


FIG. 2

The wave length at which the Du Bois effect is replaced by the Hertz effect is called the point of inversion, and is determined chiefly, according to Du Bois, by the material of which the grating is composed. The results obtained by Du Bois, however, are partly contradicted by the experiments of Braun, who pulverized platinum wires on glass, thus producing, as he assumed, exceedingly fine gratings, which in all cases showed a well marked Hertz effect.

Schaefer and Reiche have published, in a recent number of the *Annalen der Physik*, the results of a theoretical investigation, which indicate that Braun's observations were probably correct and that the Hertz effect is always produced when the diameter of the wires of the grating is small in comparison with the wave length. Hence it is desirable to repeat and extend the experiments of Du Bois and Rubens.,

HIGH VOLTAGE INDICATOR.

A simple method of determining whether a wire carries a current of high voltage or not consists in connecting the wire to earth through a Geissler tube in the manner indicated in Fig. 3. The presence of a

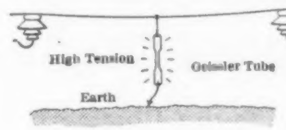


FIG. 3

high voltage current is immediately indicated by the glowing of the rarefied gas in the tube. Owing to the high resistance of the vacuum tube no "earth" worth speaking of is produced by this method. A recent number of the *Elektrotechnische Zeitschrift* describes an indicator based on this principle and intended for stationary use. Fig. 4 shows the indicator which is operated by turning up the handle *A* and thus placing the portion *B*, which contains the Geissler tube, in connection with the terminal *D*, which is connected with the high-tension circuit. The tube is observed through a little window at *C*. The axis of the mov-

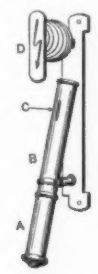


FIG. 4

FIG. 5

able arm, and, consequently, the other end of the tube, are connected with the earth. Fig. 5 shows a similar apparatus devised for permanent use, in which the tube is attached to the other parts by spring clamps.

THE ROTAMETER.

The accurate measurement of the velocity of flow of gases offers great difficulty in many experimental researches. A novel instrument for measuring this velocity has lately appeared in the market. The left-hand (Fig. 6) illustrates the principle of the apparatus, which is called the rotameter. The gas flows upward through a slightly tapering glass tube *a*. The

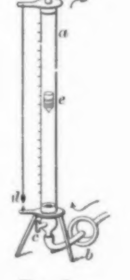


FIG. 6

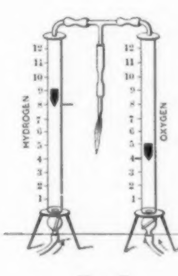


FIG. 7

supply pipe is provided with a stop cock *c* and a cotton-wool filter, inclosed in a capsule *b*. The ascending stream of gas lifts a hollow indicator *e* to a height which varies with the velocity of the current and, at the same time, sets the indicator into rapid rotation about its vertical axis, whence the name rotameter. The rotation prevents adhesion of the indicator to the wall of the tube. The flow, in liters per second, is given directly and very accurately by the portion of the indicator in respect to a scale etched on the glass tube. The scale is graduated empirically and a different scale is required for each gas.

Two or more gases can be mixed in any desired proportions, easily and accurately, with the aid of a corresponding number of rotameters. For example, hydrogen and oxygen can be mixed in the proportions required to form water, by joining the outlet pipes of two rotameters, the inlet pipes of which are connected with cylinders of compressed hydrogen and oxygen, respectively, and adjusting the stop cocks until the whirling indicators show that the flow of hydrogen is double that of oxygen. This arrangement of apparatus is illustrated by Fig. 7.

THE KERR EFFECT IN GLASS.

In 1875 Kerr discovered that double refraction is exhibited by dielectrics subjected by electric stress. The meaning of this statement is illustrated by the accompanying (Fig. 8). A horizontal glass tube *a*, the ends of which are closed by plane sheets of glass, is filled with a transparent non-conducting liquid (carbon disulphide, for example) in which two horizontal plates of metal, *b* and *c*, are immersed. By connecting these plates with the poles of an electric "influence" machine *d* or a galvanic battery of high electromotive force, an electric field is created between the plates, the lines of force running vertically in the direction of the arrows. In these conditions polarized light which traverses the tube lengthwise is found to move with different velocities, according to the direction of the plane of polarization. In carbon disulphide, for example, light which is polarized in a vertical plane, parallel to the lines of force, travels more rapidly than light polarized in a horizontal plane. (The electric oscillations of light waves are perpendicular to the plane of polarization and are therefore horizontal

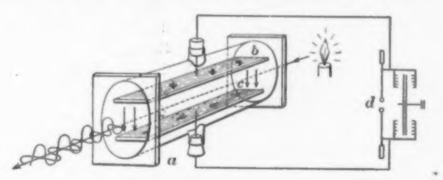


FIG. 8

in the first case and vertical in the second.) As the index of refraction of a substance is the ratio of the velocity of light in that substance to the velocity of light in air, we have here two indices of refraction, and hence the phenomenon is called electric double refraction. The difference between the indices of refraction of light polarized respectively parallel and perpendicular to the lines of force, when the fall of potential is one volt per centimeter, is called the Kerr constant. The Kerr constant for carbon disulphide was measured in 1883 by Prof. Quincke, who obtained the value 32×10^{8}. A slightly different value, 30.42×10^{8}, has been found recently by Dr. Tauern. An accurate knowledge of the Kerr constant is valuable as it enables high electrostatic potential differences to be measured by an optical method. Tauern's experiments have also confirmed the correctness of Kerr's observation of double refraction in glass subject to uniform electric stress. The value of the Kerr constant increases with the proportion of lead in the glass.

ELECTROMETER WITH VARIABLE RANGE AND SENSITIVENESS.

Measurements with the galvanometer are made much more convenient by the possibility of diminishing the sensitiveness of the instrument ten-fold, one-

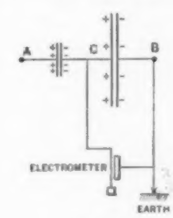


FIG. 9

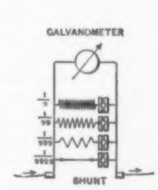


FIG. 10

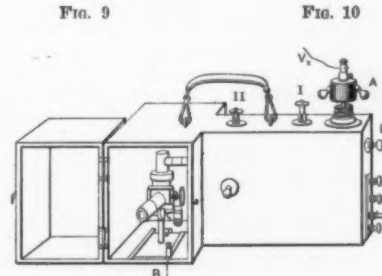


FIG. 11

hundredfold, or one-thousandfold by the use of parallel circuits, or shunts, having resistances equal respectively to 1/9, 1/99, or 1/999 the resistance of the galvanometer. Fig. 10 shows how any given current

* *Prometheus.*

strength can thus be measured by means of a single galvanometer and a series of shunts.

The need of a similar method of varying the sensitiveness of the electrometer is obvious. Dieckmann has devised a portable inclosed electrometer which can be used with twenty-one different grades of sensitiveness for measuring potentials from two volts to twenty-five thousand volts (Fig. 11). The principle of the apparatus is illustrated by the diagram (Fig. 9). Let us suppose that it is required to measure the difference of potential between the points A and B. Between these points two well insulating condensers, free from residual charge, are inserted in series. The wire C connecting these two condensers possesses a potential which approximates more closely to that of the earth the greater the capacity of the condenser inserted between this wire and the earth, or the point B, compared with the capacity of the condenser between C and A. Between the wire C and the earth is inserted the electrometer, the capacity of the instrument itself being added to that of the condenser between C and B in estimating the degree of sensitiveness.

Fig. 11 shows a Lutz chord electrometer with microscope reading on the left, and the above described potential reducer on the right. The object whose potential V is to be measured is connected with the terminal A. By means of the buttons I and II, various condensers corresponding to that between A and C in Fig. 9 can be inserted, while the buttons 1, 2, 3, 4 control the insertion of a number of other condensers, corresponding to that between C and B in Fig. 9. D is a button by means of which all parts of the interior of the apparatus with the exception of the terminal A can be simultaneously connected with the earth. By drawing out the buttons in various combinations, a great variety of grades of sensitiveness can be produced. The condensers are all of cylindrical form and contain no dielectric except air. As the Lutz electrometer does not require to be protected absolutely from vibration, this apparatus can be used everywhere, even on overland journeys and on board ship, for the measurement of differences of potential ranging from two volts to twenty-five thousand volts, to within less than one per cent.

Illuminating Engineering*

Its Value to the Commercial Man

By William T. Serrill

The writer has heard the opinion expressed that illuminating engineering is an abstruse technical science, with only an indirect, or remote, bearing on practical questions; and, consequently, that the commercial man of the electrical or gas interests, can derive little of benefit from the study of this science, or from attendance at the meetings of the Illuminating Engineering Society. The object of this paper is to show that the opinion here described is erroneous.

For the present purpose, the subject may be divided into three classes, namely: First, the design and development of lighting units; secondly, the determination of the light distribution and of other characteristics of the available units; and thirdly, the application of the available units to the spaces to be lighted, as determined by the illumination requirements.

It is evident that the commercial man is dependent upon the illuminating engineer for the design and development of the electric and gas lamps which he has available to offer to the public. The physical and chemical principles underlying both of these forms of illuminants are abstruse, and each has reached its present efficient form through invention and research on the part of scientific men. The commercial man may well say, "It is not necessary for me to master these scientific principles; I accept with thanks and put on the market the latest products of such invention; if I am free to criticise, and to state what my experience as a salesman indicates is required by the public, and if the engineers meet these requirements, I am satisfied."

It may be admitted that the commercial man need not master the principles underlying the design of lighting units, but the statement just put into his mouth shows how essential is a constant co-operation and exchange of opinion between the commercial man and the laboratory man. The latter is to a large extent dependent upon the former for a knowledge of the public taste, and of the extent to which the public purse will be opened to its gratification. In addition, the commercial man will understand the requirements demanded by the various kinds of buildings and of occupations, as affecting such points as the size of the unit, the distribution of light from it, its color, its daylight appearance, etc. The association together of these two classes of men at the sectional annual meetings of this society cannot fail to be of benefit to the art of illumination. If on this point it may seem to the commercial man that he imparts more than he receives, he should realize that it is in a good cause, and will result in the production of more efficient units, better adapted to the requirements of the consuming public.

It is evident that the commercial man, having at his command an assortment of lighting units, in his effort to sell them, must be possessed with a thorough knowledge of the salient characteristics of each of the units. For this knowledge, he is dependent upon the illuminating engineer. The illuminating engineering laboratory with which the writer is connected has furnished, or is now engaged in preparing, information regarding the gas lamps that are being sold, as follows:

Light distribution curves of lamps and globes; luminous efficiencies of lamps, globes and mantles; minimum distance from the ceiling it is safe to hang the lamps; safe distance under awnings for outdoor lamps; windproof qualities of outdoor lamps; relative emission of radiant heat from gas and electric lamps; relative intrinsic brilliancy of lamps fitted with assorted glassware; proper heights of lamps of various types, suitable for various purposes; reflective efficiencies at various angles, of various lights with standard wall papers; absorption coefficients of glassware; ignition devices; color values of the light from various lamps; strength of mantles; adaptability of lamps to various gases and pressures; loss of efficiency, during service, of lamps and mantles; examination of lamp structure and suggestions for remedy of structural defects.

Knowledge of the kind indicated in the above list is essential to the commercial man in his effort to sell, and to meet the competition of other forms of illuminants. Here there is reached another point which emphasizes the importance of the commercial man attending the metings of the Illuminating Engineering Society. At the meetings he learns how to interpret and utilize the data furnished by the laboratories. The subjects contained in the above list are of the sort that are considered and discussed at the meetings. Any salesman listening to, and taking part in, the discussions, thereby improves his efficiency by increasing his knowledge of the thing he sells.

Having considered the laboratory end of illuminating engineering, and having shown the value to the commercial man of his participation in the discussion of subjects connected with that branch, it is well now to approach the third division, that of applied illuminating engineering.

In considering this subject, one is met at the outset by the startling fact that the application of lighting units to interiors is, and from the nature of conditions must be, made by the commercial man. In any city, the electric light company and the gas company, through their canvassing departments, handle such work. There is, to be sure, the consulting illuminating engineer, who may plan a fraction of it, but it remains true that the great bulk of lighting installation work is carried on by the gas and electric interests. In the stress of competition, these interests actively canvass, and thus secure the work.

Now canvassing for light is, like other canvassing, essentially commercial work. It is organized and carried on for a direct and immediate commercial purpose, and it must be directed by a commercial head. The atmosphere of a department where canvassing is carried on, should be charged with the commercial spirit. Engineering departments, from the nature of their duties, do not develop among their employees the selling instinct. The writer does not mean to imply that an engineering education is not helpful to a salesman, or to any one in charge of a selling department. The point he wishes here to make is that a canvassing department, to be successful, should be organized as such, and should devote its energies exclusively to that purpose.

In canvassing for light, the conditions are such that generally the character of the installation must be determined by the canvasser, during his visit to the consumer's premises, and frequently in the consumer's presence. The stress of competition and the sensibilities of the consumer generally combine to make the element of time an all-important factor. The prospective customer says: "Here is an interior. Can you light it satisfactorily? Can you improve on its present lighting? How much money can we save by installing your system?" In order to secure the work at all, the canvasser must be prepared to give an immediate answer to these questions, and, in so doing, he is determining the character of the installation his company will make, in case it gets the order. In other words, the canvasser is doing the applied illuminating engineering. The fact that the orders so taken may be given to an engineering department to install, and that in this way, the plans of the canvasser may be checked, and corrected if mistaken, is not to the point. Occasionally such a change might be made, but many cases of this kind would seriously affect the business.

Having shown that practical considerations force the application of lighting units to interiors into the hands of the canvasser, it should be unnecessary to furnish an additional argument toward the education of the canvasser in the principles of illumination. Each company must solve for itself the problem of imparting this education; upon its success will depend whether or not the interiors covered by its field of operations are properly lighted. In the writer's opinion, the Illuminating Engineering Society should become an active factor in the education of the lighting canvasser. Especially should the local sections take an active part. In these, more time should be given to discussions of actual installations. Such installations, illustrated by diagram or photographic slide, when criticised and discussed in public meeting, have a high educational value. Commercial men, members of local sections, should be encouraged to present descriptions of such installations, and of interesting problems that arise in their experience.

The Illuminating Engineering Society has been adversely criticised for devoting its energies too exclusively to the abstract chemical, physical and physiological problems that pertain to the profession. Even if the charge be true, the adverse criticism is not deserved. The profession of illuminating engineering is emerging from the state of infancy; it is proper that the scientific principles which underlie the profession should have been mastered before the more practical phases of the subject come to the fore. The society is now in position to devote more time to the latter. It has been suggested that the annual sessions should consume four days, two being devoted to the scientific and two to the practical branches of the profession. The purely commercial phases of the sale and introduction of lamps should probably not be considered by this society.

At this point some commercial man arises and protests somewhat as follows: "The practice of illumination is an art, and the main qualification of the person who practices this art is experience combined with common sense. It may be true that the art is based on scientific principles, more or less abstruse, but a knowledge of these principles is not essential, any more than in the art of preparing food, the expert cook must be acquainted with the chemical and physical changes brought about by the application of heat to animal and vegetable tissue. I grant my man must be thoroughly familiar with the lighting units, and the accompanying glassware, and must be able to interpret the light distribution curves and other data furnished by the laboratories, but when it comes to the actual application of the units to the space to be lighted, judgment based on experience is the only tool he needs. There may be some cases of such complication that he may need the advice of an expert illuminating engineer, but they are few and far between. Practical conditions in most cases prevent an ideal arrangement of the lamp; these practical conditions are so numerous and so compelling as to become the dominant factors, so that the best illumination obtainable is a compromise. Outlets are fixed, and it is expensive or inexpensive to change them; the ceilings are low; columns, showcases, balconies, etc., interfere; these and numerous other practical consideration are such that, in the great majority of cases, the installation made by the consulting illuminating engineer, after calculating the illumination at all parts of the room, will be identical with that made by an experienced man, using nothing but his judgment as a guide."

The above remarks of our commercial friends are interesting, and contain considerable of truth, but there is in them no argument against the proposal to educate the lighting canvasser in the principles that underlie practical illumination. No one can argue that a knowledge of these principles will detract from

* A paper presented at the Fourth Annual Convention of the Illuminating Engineering Society, Baltimore, October 24th and 25th, 1910.

this man's efficiency; very few will have the temerity to argue that such a knowledge will not be of positive value to him.

The practice of illumination is indeed an art, but is it not also something more, namely, a profession? Those arts in which the processes are so simple that no knowledge of the underlying principles is needed in order to practise them, are arts pure and simple; in proportion as the processes become complex and involved, and as the problems contain many variable quantities, a knowledge of these principles becomes essential, and the art merges into a profession. Shining shoes and washing clothes are arts in which the processes are simple, requiring on the part of the bootblack and washer-woman no knowledge of the chemical and physical changes involved. Cooking is to a certain extent such an art, but the frequently-urged claim that it is practically a lost art, is due to the fact that most of the cooks are "practical" cooks, and that too little attention is paid to a knowledge of the underlying principles. The more complex the problems involved in illumination, the more numerous the practical obstacles, the more essential becomes a knowledge of, and a constant reference to, the principles which underlie the profession of illuminating engineering.

A word of re-assurance may here be advisable, lest the commercial man be frightened at the vast extent of learning that is expected of him. The transactions of this society, as one turns them over page by page, present many formidable propositions to any one who is not a trained scientist or an expert mathematician. The commercial man may be comfortable in the thought that these are not for him. The principles he needs are relatively simple, and such as he can easily grasp, if he appreciates their importance, and seriously applies himself to them. He should learn how to determine the amount of illumination from the curve of the lighting unit when the units are spaced at any given distance and height; and how to allow for the effects of reflection from walls and ceiling. He should maintain a drawing board for his own use, and should use it constantly, never guessing at the result when it may be ascertained by proper calculation. Most formulas that he needs in his work are given in table form for his convenience, and constants are provided for his use; it is not absolutely necessary that he should understand the derivation of the formulas, or the laws on which the constants are based, but the more he understands of them the better. He should practise to think and judge of illumination in definite units—in foot-candles; and to enable him to do this, he should understand the use of the portable illuminometer, and make constant use of this instrument in reading the actual illumination obtained by the equipments he installs. There is no better way to train the judgment than this constant checking of calculations by results. He should be a constant attendant at the meetings of one of the local sections of this society; even although he may not follow every argument or calculation, he will surely absorb from every discussion some grain of knowledge which will enable him more intelligently to meet the demands of his calling.

The profession of illuminating engineering deals with an important subject, fraught with grave consequences to the future of our race. Conserving the most vital one of those five senses which form the connecting links between the personality of the individual and the physical world, it is destined to exercise an important influence on the progress of civilization. It enlists the services of the physicist, the chemist, the mathematician, the physiologist, the oculist, the manufacturer, the architect, the artist; and in this list the commercial man holds an honorable and commanding position. No one, two, or three of the types of men here named can solve the multifarious problems of the profession. It requires the services and the co-operation of them all. The profession cannot afford to have any one of them hold aloof; and it will prosper in proportion to the degree of co-operation and of interchange of opinion that is maintained, and to the extent to which those individuals who compose each group endeavor to broaden their views by obtaining as great a knowledge as possible of the activities of the other groups. The commercial man cannot afford to remain ignorant of the progress of illuminating engineering. The best basis upon which to build the knowledge and experience of salesmanship in this commodity is a familiarity with the principles of illuminating engineering.

Correspondence

The Star Clusters

To the Editor of SCIENTIFIC AMERICAN SUPPLEMENT:

The suggestion of Mr. Arthur K. Bartlett in the SUPPLEMENT of the SCIENTIFIC AMERICAN of February 4th, that the solar system is gravitating toward the star-cluster in the constellation of Hercules, is perhaps worthy of more attention than, on a superficial view, is accorded to it. The problem, what are the laws of motion of a system of bodies subject to mutual attraction according to the law of gravitation, or any other law, cannot be solved by the mathematical methods which are available at present. In other words, the algebraic equations which define these laws cannot be obtained. Even the solution with regard to two bodies is only a partial one, since it rests on the hypothesis that the original tangential impulses took place in the same plane, which is infinitely improbable. If this solution has been attempted and accomplished on the hypothesis that the directions of these impulses crossed without intersecting one another, it has not come to the writer's notice.

Although we cannot solve the general problem, yet, according to the laws of mechanics, certain principles have been established which can give us some idea of the manner of motion of the bodies under consideration. These are:

1. The center of gravity of a system of bodies subject to mutual attraction is stationary with regard to those bodies, just as the sun is stationary with regard to the planets.

2. The sum of the areas described by the radii vectores each multiplied by the respective masses of the moving bodies is constant.

3. The vis viva of the system is constant.

From the last principle it follows, that the system can never come at rest.

The second principle establishes the fact that the nearer the bodies approach one another, the greater must be the velocity of their motion.

The first principle necessitates that all the bodies must gravitate toward one and the same point, namely, toward the common center of gravity.

When several thousands of bodies in their course gravitate toward one point, it would seem that at some time or other in the neighborhood of that point a cluster will be formed. Granting this, let us try to determine what course any one of the bodies under consideration is likely to follow.

Suppose a body is moving away from the cluster; then the attraction of the cluster will retard and finally reverse its motion.

If, at this juncture, the body is affected by no tangential force, in other words, if it has been moving in a straight line, which passes through the common center of gravity, then it will return along the same line, approaching the cluster with increasing velocity and finally reaching it. The universe is built on so generous a plan that the body here considered may traverse the cluster without coming in collision with any of the bodies composing it, no more than a comet passing through the solar system must necessarily collide with any of the planets or satellites of that system. Indeed, the fact that the stars which constitute a cluster can be observed individually and counted, shows that the distances which separate them must be very considerable. Moving as it does in a line which passes through the common center of gravity, the attractive forces which affect the body in a direction perpendicular to that in which it moves will nearly balance each other. So it must continue to move in a straight line, passing through the cluster and then departing from it with a velocity which is retarted continually, until it is exhausted and the motion of the body is reversed once more. Such a body, therefore, will simply oscillate between two points on opposite sides of the cluster and equidistant from it.

If the body which is the subject of our consideration, at the time when its motion is reversed, was moving in a direction which did not pass through the common center of gravity, then it will describe approximately an elliptical arc and in returning it may or may not traverse the cluster.

If the body does not traverse the cluster, but passes by it, then the cluster will operate upon it, as the sun does on a comet, that is, swing it around and throw it back into space, and the orbit of that body will be approximately a more or less elongate ellipse, of which the common center of gravity will be one of the foci.

If the body does traverse the cluster, it will be affected by the attraction of that part of the cluster which is bounded by a sphere whose center is the common center of gravity, and of whose surface the moving body is one of the points. The attractive forces which the bodies outside of that sphere exert on the body under consideration will nearly neutralize each other. Virtually the conditions which determine the motion of the body here considered will be the same as those which govern the motion of a body that does not enter the cluster. The orbit of every body, therefore, that traverses the cluster and does not pass through the common center of gravity will likewise be approximately a more or less elongate ellipse, having the common center of gravity for one of its foci.

As to the motion of the bodies composing the cluster, each body of the system in its turn will approach the common center of gravity, and the cluster therefore is composed of those bodies which temporally are in the neighborhood of that center.

Of course all these conclusions are very rude approximations, and the orbits of a stellar system are not pure ellipses, no more than are the orbits of the planets, satellites and comets of our solar system. Yet it would seem that the theory here presented gives a fair idea of the interaction of a large number of bodies subject to mutual attraction. Perhaps the best example of the probable motion of the bodies of a stellar system is afforded by the comets which appertain to the solar system.

Although the passage of a body appertaining to a stellar system through the central cluster of that system does not necessarily involve collision with other bodies, yet it does not follow that such collision does not occur from time to time. On the contrary, occasional collisions are not only probable, but apparently necessary for the preservation of the caloric energy of the system.

Perhaps every star-cluster is the center of a stellar system and the furnace, in which the bodies belonging to the system regain the heat, which they have lost during their long excursions in space.

Pella, Iowa. JOHN NOLLEN.

CONTENTS

INDEX OF INVENTIONS

For which Letters Patent of the United States were Issued for the Week Ending March 14, 1911

AND EACH BEARING THAT DATE

[See note at end of list about copies of these patents]

Acetylene, dissociating, J. M. Morehead... 986,489
Acoustical instrument, L. Lumiere........ 986,477
Adhesive plaster, M. Taylor.............. 986,655
Air, apparatus for the production of compressed, M. K. Kirilloff.............. 986,577
Air chamber, suction, F. B. McNinch..... 986,734
Air lock, W. H. Flaherty.............. 986,970
Airship, J. O. Brookbank.............. 986,434
Airship, C. A. Kuenzel.............. 986,578
Alarm system, electrothermostatic, A. Goldstein.............. 986,704
Album, photograph, C. W. Crogan....... 986,962
Alloys of titanium with other metals or the like, producing, A. J. Rossi.. 986,502
Amalgamator, F. J. Hoyt.............. 987,071
Ammunition conveyer, G. C. Plummer..... 986,753
Amusement of the public, apparatus for, G. Young.............. 987,029
Animal trap, H. J. Hagge.............. 986,460
Animal trap, S. McDonald.............. 986,928
Asparagus harvesting tool, A. A. Smith.. 986,773
Automobile attachment, C. R. West...... 986,613
Automobile door opening and closing attachment, S. J. Way.............. 986,880
Automobile safety fender, I. Ksiazek..... 986,832
Automotor, turbine driven, S. Z. de Ferranti, reissue.............. 13,217
Awning, Paro & Hadsell.............. 986,852
Baker, apple, Fowler & Mead............ 987,058
Baking machine, pastry, J. Allenson..... 987,032
Bale hook, trip, G. Rentschler.......... 986,644
Baling machine, hay, C. L. Inman...... 986,986
Barge, self unloading, A. F. Wiking..... 986,529
Bearing, antifriction, H. Stuebner...... 986,871
Bearing for car and other wheels, centrifugal oiling, F. A. Warren.......... 986,925
Bearing for car wheels, centrifugal oiling, F. A. Warren.............. 986,526
Bearing for shafts, compensating thrust, E. Kirk.............. 986,635
Bearing, resilient, O. Ritz.............. 986,862
Bearing, roller, H. B. Gillette....986,453, 986,454
Bed case, disappearing, L. Holmes....... 986,633
Bed or couch, W. J. Grotenhuis.......... 987,064
Bed spring, corner, L. C. Lewis.......... 986,836
Billiard table cushion, J. S. Burroughes.. 986,543
Binder, loose leaf, H. B. Bristol....... 986,542
Binder, loose leaf, A. Waguiere.......... 986,609
Binder, loose leaf, J. L. McMillan....... 986,735
Binder, loose leaf, Dawson & Heeter..... 986,910
Binder, loose leaf, J. F. Dixon......... 986,911
Blast furnace, F. J. Zippler.............. 986,792
Block machine scraper, I. Grogg.......... 986,450
Blowing engine or compressor, G. B. Petsche.............. 986,752
Boat discharging mechanism, W. W. Robinson.............. 987,017
Boat hull and ballast means therefor, F. W. Frampton.............. 987,059
Bolt lock, W. A. Scott.............. 986,510
Bolt making mechanism, F. F. Deeds..... 986,697
Book cover and holder, note, R. P. Shapro. 987,019
Boring and turning machine, A. F. Nathan 986,493
Bottle cap and remover, combined, Wallace & Forsyth.............. 986,524
Bottle capping machine, H. E. Marshall.. 986,839
Bottle crowns or caps, machine for manufacturing, B. L. Buchanan.......... 987,084
Bottle filling and stoppering machine, Stockel & Popp.............. 986,603
Bottle holder, nursing, M. D. Dekle....... 986,445
Bottle, non-refillable, F. A. Stephenson... 986,516
Bottle, non-refillable, J. W. Collins...... 986,546
Bottle, non-refillable, L. J. Loeffelman... 986,838
Bottle, two-part, E. N. Breitung........ 986,963
Brake operating machine, W. W. Irwin... 986,826
Breast evacuator, H. F. Milligan......... 986,738
Brickmaking machine, P. J. Mead........ 986,584
Bridge score, pocket, H. W. Bennet...... 986,675
Brush, J. F. Bowditch.............. 986,679
Brush, fountain, L. J. Mahler.......... 986,926
Buggy wrench, M. A. Johnson............ 986,716
Building blocks, making hollow, F. Burcharts.............. 986,798
Bumping post, A. E. Schultz.............. 986,500
Burglar alarm, L. S. Bander.............. 986,671
Button and button and loop clasp, C. W. Stimson.............. 986,518
Button holder, A. H. Cushman.......... 987,051
Button hook, J. Johnson.............. 986,989
Cabinet, seed testing, B. H. & W. C. Adams.............. 986,426
Cabinet, sleeping, A. Berchem........... 986,430
Cabinet, vending, M. R. Maher.......... 987,005
Calculating machines, etc., key bar locking mechanism for, W. W. Hopkins.. 987,068
Can. See Oil can.
Can heads, machine for applying adhesives to, P. Kruse.............. 986,469
Can heads, machine for applying adhesives to, P. Kruse.............. 986,470
Can marking machine, F. P. Ryder..... 986,867
Candy forming and cutting machine, S. Vessot et al.............. 986,878
Car and apartment heating and ventilating system, M. McGerry.............. 986,731
Car axles, means for driving generators from, W. I. Thomson.............. 986,650
Car door, grain, J. M. Rush.............. 986,646
Car door lock, T. H. Watts.............. 986,786
Car door lock, Byrne & Wise........... 986,799
Car door motor controller, J. F. McElroy. 987,006
Car fender, street, J. J. Kelly.......... 986,990
Car heating and ventilating system, M. McGerry.............. 986,732
Car partition, adjustable, J. Dixey....... 986,810
Car, railway freight, Hern & Veil........ 986,981
Car switch, street, L. Z. Preston........ 986,858

Carbureter, B. Ivor 986,572
Carbureter, H. E. Fogel 986,700
Carbureter for gas and gasoline engines, Swagell & Padfield 986,605
Card holder, playing, C. Wilder 986,665
Card punching machine, P. Matthijssen.. 986,479
Caster, H. P. Eilers 986,812
Chain guide for sockets, pull, O. E. Kenney 986,991
Chain, hitching, C. H. Gordon 986,973
Chainless hand brake, adjustable, F. F. Ray 986,499
Chair, platform, and receptacle, combined, N. L. Carney 986,686
Change mat, J. I. Moorehead 986,936
Chocolate, biscuits, sugar, and the like, mold for, M. Reiche 986,500
Chuck, A. F. Schade 986,047
Chuck, E. A. Clark 986,689
Cigar holder, W. V. Smiley 986,950
Circuit breaker, automatic, A. E. Greene.. 986,708
Clamping tool, R. E. Jack 986,464
Clock, V. E. Duncanson 986,447
Clock, watchman's, F. Hardinge 986,630
Closet bend or connection, F. W. Carlson. 986,905
Cloth carrying machine, S. Hardy 986,822
Clothes drier, M. Herscovits 986,711
Clothes drier, W. L. Cummer 986,804
Clothes line adjuster, D. W. Rantine.... 987,015
Clothes line support, B. F. Hiatt 986,983
Clothes rack, J. L. Wilson 986,788
Clutch, H. Knapp 986,923
Clutch mechanism, friction, G. A. Schacht 986,947
Clutch mechanism, hydraulic feed, S. H. Keefer 986,830
Cock, ball, T. W. Ryan 986,866
Coffee urn, H. R. Hansen 987,096
Coin handling apparatus, A. J. Nott...... 986,939
Collar attachment, M. G. Polk 986,755
Collar, double shirt, C. Hyatt-Woolf...... 986,825
Comb, G. Grosscup 986,918
Crumb cleaner, F. L. Vordemfelde 986,785
Combing machine, circle, Whitehead & Galloway 986,616
Compensating device, J. F. Raders........ 986,498
Compressor, rotary, A. C. Roessler........ 986,502
Concrete column, J. A. McKee 986,733
Concrete construction mold, H. C. Seipp.. 986,767
Concrete construction, reinforced, H. L. Lewen 986,474
Concrete or like walls, double sided framework for the construction of, P. Hedrich 986,565
Condenser, acid, Moore & Hall 986,846
Conduit, vapor, Lockwood & Seltz........ 986,476
Confection cone case, P. E. Waldvogel.. 986,610
Connecting rods, forming steel, L. W. Coppock 986,547
Converter, L. G. Woods 986,534
Cooking utensil, L. Nelson 986,848
Cooler. See Liquid cooler.
Coop, brood, J. E. Fulton 986,703
Copper from porphyry ores and the like, recovery of, G. Schneider 986,508
Cord, etc., machinery for manufacturing or treating lengths of, T. Sloper 986,600
Core forming machine, sand, L. M. Hennessy 986,980
Core stripper, Kennedy & Gaylord........ 986,831
Cork puller, M. L. M. Peck 986,855
Corset, J. E. Strouse 986,779
Cotton chopper, R. B. Miner 986,933
Cotton stalk stripping and breaking machine, Daniels & Kuhne 986,551
Coupling and steering device, A. W. Hindman 986,568
Cover attachment, T. McCabe 987,087
Cow tail holder, L. H. Bigelow 986,894
Crank hanger, M. Schenck 986,596
Crate, shipping, R. & R. Muehr 986,587
Crutch, C. E. Kritsch 986,999
Cultivator, R. E. McNamara 986,481
Cultivator, S. H. Tinsman 986,607
Cultivator, J. W. Beckman 986,674
Current motor, L. Guynn 986,919
Dam construction, L. Jorgensen 986,718
Damper, G. W. Fogelsong 986,971
Damper regulator, automatic, W. J. Turner 986,658
Deflocculation and product thereof, E. G. Acheson 986,793
Dehydrating apparatus, F. T. Stare........ 986,602
Dental impression tray, J. W. Greene..... 987,063
Die stock, W. H. Leaver 986,473
Dipper door, F. W. Thomson 986,522
Display device, E. Woodrum 987,028
Display rack for rocking chairs, P. O. McIntyre 987,078
Display rack for trunks, C. A. Kuntzendorf 986,725
Display stand, T. P. Briody et al. 986,433
Door apparatus, safety, N. Girrens........ 986,816
Door checks and closers, door stop for, W. K. Henry 986,710
Door fastener, H. Kappele 986,465
Door, grain, J. Oliver 986,746
Drain pipe, C. W. Osborne 986,940
Drawing sharp edges on metallic bodies, machine for, C. O. Halling 986,820
Drier. See Clothes drier.
Drinking cup collecting apparatus, A. R. Hussey 986,571
Drinking fountain, O. Smith 986,775
Drinking fountain, poultry, F. W. Ruggles 986,945
Drinking straws, device for dispensing, G. Meredith 986,929
Dye, yellowish red vat, P. Thomaschewski et al. 986,521
Electric conductor safety coupling, A. Belgoder 987,036
Electric cut-out, T. E. Murray 986,744
Electric iron, Moodie & Ball 986,488
Electric light fixture, J. S. Coming....... 986,550
Electric machine, dynamo, C. M. Page.... 986,748
Electric machine, dynamo, J. Burke....... 987,044
Electric switch, H. Hull 986,714
Electric switch, Woods & Sayles 986,958
Electric switch, iron clad, V. Hope....... 986,570
Electrical circuit controller and alarm, A. Goldstein 986,707
Electroplating machine, J. W. Heaphy.... 986,823
Elevating and lowering device, F. M. Zimmerman 986,888
Elevator doors, automatic actuator for, H. G. Peelle 987,011
Elevator for ash cans and the like, R. Messlin 986,483
Engine controlling device, internal combustion, O. Podhajsky 986,754
Engines, driving gearing for traction, J. W. Shelburne 987,020
Engines, moistener for internal combustion, C. C. Rich 986,757
Expansion joint, J. Scott 987,089
Explosive, J. B. Bronstein 986,900
Eyeglasses, T. F. Baber 986,795
Fare register, automatic, D. J. Toal....... 986,523
Feed mixer, F. I. Derby 986,553
Feed water cleaner and heater, E. Efran 986,968
Feed water regulator, F. N. Connet....... 987,048
Fence tie, G. H. Cock 986,545
Fertilizer distributer, J. H. Mathews...... 986,840
Fertilizer, making, Colburn & Broadbent.. 986,623
Fibrous materials, machine for treating, C. T. Drake 986,624
Fifth wheel, W. B. Messink 986,482
Filament for incandescent electric lamps, metallic, K. Farkas 986,558
Filament, variegated corn, H. D. Perky.. 987,089
Filing case, adjustable, H. H. Sellers..... 987,018
Fillet cutter, J. O. Schmitt 986,507
Filter and dispenser, liquid, A. Kenney.. 986,720
Filter, water, J. Kneen 986,998
Finish, removing, J. M. Wilson 986,531
Fire pot, R. Rouse, Jr. 986,864
Fish hook, J. Olson 986,747
Floral and display refrigerator, R. L. Tilghman 986,875
Fly trap, P. Lagodimos 986,833
Fly wheel, W. H. Heine 986,978
Food from cactus, making stock, J. H. Glazier 987,062
Food from cereals, manufacture of, H. D. Perky 987,088
Foot wearing apparel, cushioning device for, J. S. Young 986,666
Footwear, stiffening the toes and heels of, E. Liebmann 986,475
Fork. See Hay tedder fork.
Frame construction, side, O. S. Pulliam... 987,013
Fruit bag, T. J. Jackson 986,573
Fruit clipper, F. M. Bonta 987,086
Fruit picker, T. H. Heberling 987,066
Funnel signal, J. Q. Adams 986,535
Furnace, C. Wegener 986,881
Furnace, H. Moor 986,934
Furnace arch, F. Girtanner 986,455
Fuse, self-adjusting, J. O. Holton, Jr.... 986,463
Gage movement, Blanchard & Crocker.... 987,039
Game, G. W. Bugbee 986,683
Game recorder, A. C. Fluschman 987,056
Garment carrier, Katz & Barnett........ 987,074
Garment creaser, O. G. I. O'Heir.......... 986,850
Gas alarm, A. B. Jacobus 986,715
Gas burner, artificial, J. Weintz 986,663
Gas burners and like fittings, supporting means for globes of inverted incandescent, A. Bray 986,432
Gas generator, acetylene, J. N. Tweedy.. 986,784
Gas generator, acetylene, L. F. Filloon.. 987,055
Gas, making, J. J. Nix 986,495
Gas tester, J. E. Carney 986,685
Gear for power transmission, hydraulic variable, A. Sundh 986,780
Gearing, T. Coventry 987,049
Gearing, change speed, C. Cotta 986,444
Gearing, friction transmission, G. B. Eaton 986,811
Gearing, incased, E. M. Wheelock 986,614
Gearing, reversing, W. W. Henderson..... 986,631
Gearing, transmission, S. W. Blevins..... 986,677
Glass grinding disk, W. B. Mayo 986,480
Glove attachment, G. A. Moss 986,491
Glue boiler, C. E. Francis 986,560
Governor, engine, J. W. Sargent 986,762
Grass trimmer, J. B. Sinderson 986,598
Grater for culinary use, J. Kasarda....... 986,575
Grinder clamp, G. E. Kent 986,466
Grinding machine, hob, P. Catucci 986,688
Gum, chewing, T. J. Lynch 987,003
Handle. See Reversible handle.
Harrow, A. & R. E. Schley 986,507
Harrow, Naylor & Moore 986,745
Harrow, rotary, McGee & Williams........ 987,007
Hat pin fastener, C. Hierl 986,824
Hat pin guard or protector, W. R. & T. D. Tomlinson 986,874
Hat pin protector, J. H. Mateer 986,927
Hay press, I. C. Terry 986,873
Hay press, automatic, Parvin & Muse..... 986,750
Hay rack, A. Kirsch 986,468
Hay tedder fork, Shaw & Holmes 986,511
Hemp breaking machine, W. H. Atwood.. 986,538
Hinge, R. L. Murdock 986,742
Hitching device, J. B. Plato 986,591
Hitching device, I. K. Shero 986,768
Hoe and rake, combined, H. L. McKibbin. 987,008
Hoisting engine, pneumatic, Shields & Lamb 986,949
Horse holder, J. T. Wallis 986,879
Horse overshoe, C. A. Conover 986,964
Horseshoe, T. F. & D. F. Farley 986,914
Horseshoe calk, J. P. Van Wyck 986,956
Hose coupling, H. W. Thomas 987,026
Hub, wheel, M. C. Shea 987,090
Hydrocarbon burner, V. H. & J. H. T. Mills 986,739
Hydrocarbon burner, R. Hoffman 987,067
Ice box, A. Grinke 986,917
Ice creeper, A. Scaramella 986,763
Ice freezing tank, J. H. Lewis 986,835
Inkstand, F. M. Ashley 986,536
Inner tube, J. T. Lister 986,637
Insect destroyer, E. R. Lyon 986,925
Insulator, D. H. Friend 986,702
Internal combustion engine, N. E. Davies. 986,552
Ironing machine, C. H. Mattice 986,729
Ironing table, S. M. Durfee 986,912
Jack, R. F. Schofield 986,868
Jointers, feed attachment for hand, G. D. Trogdon 986,782
Keg or barrel making machine, F. E. Keyes 986,995
Kettle lid, M. A. Lewis 987,077
Kilns, repairing the linings of rotary cement, Morrison & Loselle 986,741
Ladder, extension, C. C. Stevens 986,517
Ladder, step, A. S. Soule 986,953
Lamp, Eber & Lentz 986,557
Lamp, W. F. Persons 986,590
Lamp burner, incandescent vapor gas, C. H. Smith 987,022
Lamp, piano, J. G. MacKenzie 987,004
Lamp socket, electric glow, T. E. Murray. 986,743
Lamps, gauze of miners' safety, E. A. Hallwood 986,461
Land clearing and digging machine, C. A. Reeves 987,016
Last forms for upper patterns for boots or shoes, blank for, A. E. Whitelaw 986,884
Latch, door, S. Skowronski 987,021
Laundry shaper, W. A. Zeidler 986,959
Leather working machines, sectional work support for, F. J. Perkins 986,497
Lemon squeezer, F. Carroll 986,800
Level, M. E. Comstock 986,909
Level, O. L'heureux 986,924
Life saving device, A. L. Bideaux 986,431
Lifter. See Plate lifter.
Lifting jack, J. B. Taylor 986,781
Light or other fixture, adjustable, W. L. Franks 986,451
Link, removable, E. J. Nixon 986,938
Linoxyn and like products especially intended for utilization in the linoleum manufacture, manufacturing, A. Genthe 986,562
Liquid cooler or receptacle, L. Zelam 987,031
Liquid fuel governor, G. E. Witt 986,791
Lock, L. R. Hibbard 986,632
Lock, N. Triantafilo 986,657
Lock, G. De Cesare 986,808
Lock, J. Buday 987,043
Lock bolt, safety, H. T. Battin 986,539
Lock indicator, H. G. Voight 986,659
Loom compensating head gear, S. S. Jackson 986,634
Loom, weaving, G. E. Levy 987,080
Looms, evener frame for tuft fabric, J. A. Clark 986,441
Lubricating apparatus, W. R. McKeen, Jr. 986,734
Lubricating device, J. C. Nichol 986,849
Lubricator, F. E. Seibert, Sr. 987,082
Lubricators, operating device for force-feed, E. Sundvall 986,872
Magnetic separator, A. Dings 986,554
Mail box, Smith & Kumming 986,951
Mainspring winder, F. R. Cunningham.... 986,695
Mantle fitter's tool, T. J. Litle, Jr. 986,638
Manure and garbage incinerator, Pattiz & Sippel 986,853
Manure spreader, T. Brown 986,903
Mapping machine, automatic, M. Bustamante (h) 986,437
Measuring and marking instrument, J. E. Tschop 986,783
Measuring apparatus, D. C. McCan........ 986,730
Meat sawing or cutting machine, G. T. Francisco 986,450
Meat smoking device, M. Heinemann...... 986,566
Medical apparatus, E. A. Babler 986,618
Merry-go-round, E. O. Spillman 987,023
Metal bending machine, I. W. Hoover.... 986,713
Metals dense, rendering porous, C. E. Swett 986,519
Metallic bodies, treating, A. J. Rossi...... 986,504
Metallic body, A. J. Rossi 986,645
Mining apparatus, placer, C. Finkbeiner.. 986,626
Miter box, F. Paff 986,851
Mixer. See Feed mixer.
Moistener, envelop, K. Hjertquist 986,984
Moisture proofing hygroscopic powder materials, H. E. Miller 987,070
Molding clay articles, apparatus for, W. D. Frerichs 986,701
Mortising machine, wood, W. B. Haigh.. 987,065
Motors, governing of fluid-operated, Parsons & Carnegie 986,943
Motors operated by hot fluid, means for preventing a quick heating of, C. A. Parsons 986,941
Mower grass catcher, lawn, H. F. Wessel, Jr. 986,883
Muffler, woven tubular, C. Seidman........ 986,869
Music leaf turner, E. Scardaccione........ 986,764
Music sheet driver, F. W. Draper 986,556
Nut, lock, C. T. Drake 986,446
Nut, lock, E. J. Murdock 986,492
Nut lock, A. H. Stephens 986,778
Nut lock, J. H. Light 986,837
Oar lock, J. M. Smith 986,774
Oil can, I. H. Kinch 986,722
Optical reversing system, C. Moller...... 986,642
Opticians, fitting stand for, J. Friedlander 986,972
Ore cooling apparatus, J. B. Etherington. 986,813
Ore crusher, roller, L. C. Trent 986,608
Ore roasting furnace, Heins & Freeland.. 986,709
Packing case, J. H. Killion 986,467
Packing, piston, R. A. Fowden 987,057
Padlock, Sage & Maes 986,595
Pail hanger, W. F. Weathers 986,660
Paper box, L. W. Keyer, Jr. 986,721
Paper sheets, machine for the manufacture of, F. E. Keyes 986,993
Paper tube making machine, F. E. Keyes 986,994
Paving block, F. Galgano 987,060
Pen and pencil holder, pocket, Fraser & Fox 987,085
Pencil, C. W. Boman 986,896
Pencil sharpener, S. W. Ito 986,987
Photographic negative, J. T. Clarke 986,443
Photographic printing frame, I. Foedish. 986,915
Pianos, sliding panel for pneumatic, W. G. Betz 986,621
Picture film, F. B. Thompson 987,092
Picture taking and exhibiting machine, J. J. Pink 986,857
Pile tube, J. McGranighan 986,819
Pipe and angle cock holder, combined train, S. H. Campbell 986,544
Pipe cutting machine, automatic, D. A. Mudd 986,937
Pipes, coupling, F. Sargent 986,506
Pipes, strainer section for flexible metallic, L. J. Bordo 986,678
Pivot light, P. B. Donahoo 986,966
Plaiting attachment, hand, L. M. King... 987,075
Plane, E. A. Schade 987,081
Planing machine and attachment, W. A. Perkins 987,012
Planter, corn, N. S. Sibert 986,513
Plate lifter, M. L. M. Peck 986,854
Plow attachment, subsurface packing, Erb & Bloom 987,053
Plow for plants, weed, J. E. Caldwell.... 986,438
Plow hitch, non-side draft, H. S. Busby.. 987,045
Plow motor guide wheel, E. M. Wheelock 986,615
Pneumatics, leak regulator for primary, M. Clark 986,442
Pocket, reinforced, J. Bernstein 986,676
Post. See Bumping post.
Post mold, G. W. Wallin 986,957
Pot for containing beverages, T. H. Russell 986,805
Potato cleaning apparatus, B. J. Brouwer 986,681
Power press, Derbyshire & Longaker..... 986,800
Press, Palmer & Smith 986,496
Press, G. D. Parker 986,589
Press, C. N. Frey 986,628
Printer's cabinet, rotary, T. F. Haller... 986,975
Printing color attachment, I. L. Wild.... 986,530
Projectiles, cap for armor piercing, A. G. M. Jack 987,073
Propelling vessels, F. W. Schroeder...... 986,766
Pulley, H. J. Gilbert 986,629
Pulley, Bergenthal & Keller 986,961
Pulley, friction, H. R. Herr 986,567
Pulp articles, machine for making, F. E. Keyes 986,996
Pulp machine, M. Hanson 986,976
Pulp, machine for felting, F. E. Keyes... 986,997
Pulverizing machine, G. L. Pratt 986,756
Pump, centrifugal, F. H. Jackson 986,827
Pump governor, steam air, W. K. Rankin. 987,080
Pump operating device, S. M. Gard....... 986,561
Pumps, automatic start and stop feed for oil, Sherman & West 986,512
Rail bond, Humason & Odell 987,072
Rail brake, third, W. M. Dilliard 987,052
Rail joint and fastener, J. T. Ashton..... 986,891
Rail joint and rail fastener, S. A. Briney. 986,899
Rail joint chair, W. H. Round 986,863
Railway gate, automatic, G. Barr 986,428
Railway rail anticreeper, J. J. Quinlon.... 986,860
Railway rail stay, P. W. Moore 986,935
Railway road-bed and track construction, J. N. D. Brown 987,041
Railway safety appliance, cable, E. P. Dawley 986,807
Railway safety device, J. T. Andrew..... 987,004
Railway tie, Axelson & Desmond 986,699
Railway tie, cement and steel, W. J. Horn 986,920
Railway tie plate, J. W. Doster 986,698
Razor stropping device, J. A. Harrington. 986,564
Recorder. See Game recorder.
Reflector, automobile lamp, P. C. Avery... 986,668
Refrigerator, E. W. Shirk 986,770
Refrigerator, H. Pries 986,859
Refrigerator, vacuum, P. A. Bayless....... 986,673
Refuse destructor, F. P. Rudder 986,594
Rein holder, N. A. Archibald 986,890
Relay, electrical, C. O. Poor 986,643
Resilient wheel, R. R. Hage 986,563
Resilient wheel, E. S. Shanklin 986,948
Respiratory apparatus for firemen or others, C. E. Chapin 986,917
Reversible handle, W. Behm 986,796
Roof, A. A. Smith 986,514
Roof bracket, W. Graffam 986,456
Rosette, B. Nealis 986,494
Rotary engine, Lindley & Schreier 986,636
Rotary engine, W. L. Merrill 986,641
Rotary steam engine, R. I. Miller 986,932
Rubber heel for boots and shoes, detachable, C. H. Chapman 987,047
Rubber waste, recovering, E. E. A. G. Meyer 986,931
Rule, folding steel, R. J. Simpson 986,772
Ruler, I. C. Walk 986,611
Safety can for hydrocarbon liquids, E. J. Becker 986,429
Safety gate, J. Jones 986,574
Sash lock, E. A. Donat 986,555
Sash structure, E. M. Baker 987,034
Saw handle, J. F. Mixon 986,487
Saw set, E. M. Conklin 986,693
Scale recording and registering attachment, weighing, M. Maurer 986,640
Screen frame corner piece, E. A. Cary.... 987,046
Seal, car, H. J. Ward 987,083
Seal, gas meter, J. Graham 986,818
Seat construction, spring, F. B. King..... 986,723
Secondary or storage battery, B. Ford 986,449
Separator, B. Long 986,581
Sewer cleaner, J. M. Holdaway 986,462
Sewing machine, F. T. Strobeck 986,652
Sewing machine attachment, B. S. Alsop.. 986,794
Sewing machine feeding mechanism, W. S. Brown 986,682
Shampoo cap, L. & K. G. Lee 986,728
Sharpening device for slicing machines, Wolff & Schaefer 986,617
Sheet feeding machines, stop register for, H. C. La Batt 986,726
Shells, apparatus for feeding, R. H. Standish 986,777
Shingling gage, C. W. Field 986,625
Ship construction, J. Reid 986,861
Shock absorber, Ciglia & Pelletier 986,622
Shock absorber, C. M. Burton 986,904
Shock absorber, J. M. Jackson 986,921
Shock gatherer and loader, O. Johnson.... 986,717
Shocking machine, W. I. Cubbage 986,803
Shoe fastener, H. C. Johnson 986,988
Shoe, roofer's, H. E. Eves 987,054
Shoe tree or form, P. A. Bowen 986,680
Shoe, water, K. Heilmann 986,979
Shoe, wet proof, J. A. Kelly 986,576
Shovel handle, C. H. Roscoe 986,761
Show case, I. Anderson 986,667
Sifter, ash, J. A. Lapointe 986,727
Sign, illuminated, J. Hotchner 987,070
Sign, illuminated electric, J. Hotchner.... 987,069
Signal. See Funnel signal.
Signal apparatus, R. Berrenberg 987,037
Signal lock, H. Blank 986,962
Signaling means, selective, I. F. Manny... 986,639
Sink strainer and waste pipe cleaner, combined siphon, B. P. Smith 986,601
Skate holding clamp, H. Roberts 986,501
Skidder raising device, Carlton & Miner.. 986,440
Skirt supporter, C. J. Shippen....986,769, 987,091
Snow melter, W. J. Saxon 986,946
Soap, A. Welter 986,527
Sound distributing horn, W. S. Cobb....... 986,908
Spark arrester, S. D. & A. A. Sizer....... 986,590
Speed of motor cars and other vehicles, apparatus for limiting the, W. Roper. 986,503
Speed reducer for power generators, J. G. O'Kelly 986,588
Speedometer supporting and driving mechanism, J. H. & E. W. Bullard........ 986,684
Spigot, J. P. Tarr 986,520
Spinning, doubling, and twisting machine, S. Z. de Ferranti 986,699
Spinning, twisting, and the like machines, spindle support for, G. W. Farnham.. 986,814
Spring wheel, Crawford & Sauer 986,549
Stanchion, cattle, C. O. Braun 987,040
Staple feeding mechanism, O. S. Sturtevant 987,024
Starch, manufacture of, Bauer & Speck. 986,540, 986,541
Steam boiler C. W. Todd 986,876
Steam engine, N. G. Herreshoff 986,982
Steam engine, G. W. Baker 987,035
Steam generating plant, M. W. Sewall, 986,648, 986,649
Steam trap, C. A. Dunham 986,967
Steamboat wheel, J. B. Burch 986,435
Steering gear, F. Werndl 986,882
Stiffening device, garment, H. L. Blackwell 986,895
Stock-taking device, C. J. Strom 986,955
Stoker, automatic, A. R. Selden 986,870
Stoker, mechanical, L. F. Torrey 986,877
Store service apparatus, J. P. Gately..... 986,705
Stove, heating, S. A. Johnson 986,922
Stretchers in ambulances, means for supporting, J. T. Sheets 986,650
Switch. See Car switch.
Switch frog, J. W. Walls 987,027
Switch lock, G. Wuelser 986,887
Tag, G. T. Riebel 986,759
Tambour frame, R. E. Collier 986,692
Tapping machine, L. Clark 986,690
Target throwing trap, E. D. Fulford...... 986,815
Taximeter or fare indicator for hired vehicles, P. Richert 986,758
Teapot, coffee pot, and other infusing vessel, L. L. Grimwade 986,458
Telegraphic tape perforator, G. A. Arnold. 986,427
Telegraphy, reflector for wireless, R. D'Antonio 986,806
Telegraphy, space, J. S. Stone 986,651
Telephone body support, V. Tardieu....... 986,606
Telephone circuits and switching mechanism, secret service, A. K. Adriano.... 986,889
Telephone locking device, W. A. Soles.... 986,952
Telephone system, A. H. Weiss 986,787
Thermostat, L. L. Claxton 986,801
Thill attachment, vehicle, T. E. Gallup... 986,704
Thread cutting mechanism, H. P. Kraft.. 986,724
Tidal hydraulic power plant, A. Hanss.... 986,821
Tile and the like, machine for making, C. G. Elmore 986,448
Timber with a preservative fluid, treating, J. G. Paty 986,751
Time recorder, Green & Eaton 986,457
Tire, V. O. Mervine 986,930
Tire shoe, vehicle, T. F. Baldwin 986,670
Tires, combination pressure gage and pump connection for pneumatic, D. Barnard 986,672
Tobacco pipe, F. H. Bush 986,436
Tongue and groove joint, T. E. Camp..... 986,439
Tool holding and driving device, F. H. Kasperson 986,829
Tool operating machine, A. Perrett........ 986,856
Tooth crown, reinforced, S. G. Supplee.... 986,653
Toy device, E. Komar 986,578
Toy, musical advertising, T. S. Spivey.... 986,776
Toy, pyrotechnic, L. A. Petow 986,944
Toy, sounding, R. O. Barler 986,892
Train coaling device, moving, C. M. Miller 986,484
Trap, A. C. Warner 986,612
Traps and clean-outs for soil pipes, cover for, L. & F. Nair 986,847
Trolley, J. S. McCabe 986,842
Trolley wire hanger, W. A. McCallum.... 986,843
Trousers stretcher, J. H. Berry 986,893
Truck, J. J. Laber 986,580
Truck, barrel lifting, F. A. Moore........ 986,585
Truck, car, J. Allison 987,033
Truck side frame and journal box, car, G. G. Floyd 986,559
Truck side frame, car, O. S. Pulliam..... 987,014
Trunk fastener, P. Mayfield 986,841
Tube. See Inner tube.
Tube, Anderson & Buchanan 986,960
Tube bending machine, R. Tattu 986,654
Tubes from ductile metal, producing thin hard, J. E. Wilson 987,093
Turbine, de Laval & Fagerstrom 986,472
Turbine, Parsons & Cook 986,749
Turbine, C. A. Parsons 986,943
Turbine blade strips or sections, producing, L. A. Haines 986,974
Turbine, fluid operated, E. Brown.986,901, 986,902
Typewriters, sheet and envelop feeder for, W. H. & R. B. McArdle 987,097
Typewriters, variable line spacing mechanism for, W. D. Fricks 986,916
Typewriting machine, C. F. Lagauke...... 986,471
Typewriting machine, H. H. Steele........ 986,515
Typewriting machine, J. C. McLaughlin... 986,583
Umbrella, windproof, J. T. Wolfe 986,532
Valve, G. E. Crookshank 986,694
Valve, Schoeneck & Warne 986,705
Valve, C. D. Lukens...........987,000 to 987,002
Valve, W. H. Curtin 987,050
Valve and tube cleaning device, ferrule, W. P. McCloskey 986,844
Valve arrangement for fluid transmission gears, H. Lentz 986,834
Valve, flushing, J. H. Mahoney 986,478
Valve for train pipe couplings, automatic check, J. C. Kepner 986,992
Valve mechanism, W. K. Rankin 986,592
Valve operating mechanism, flushing, J. M. Young 987,030
Valve, steam, air, and water trap, J. E. Boegen 986,797
Valve, thermostatic, F. W. Robertshaw.. 986,760
Vat washing machine ring, H. Hipp....... 986,712
Vehicle control levers, locking device for motor, E. P. Ashton 986,537
Vehicle spring, Escalante & Sirgado...... 986,969
Vehicle top, folding, J. H. Wooddell...... 986,533
Vehicle wheel, H. C. Gibson 986,452
Vehicle wheel, Carroll & Rowles 986,687
Vehicle wheel, C. Collier 986,691
Vending apparatus, A. R. Wetherly........ 986,664
Vending machine, coin, Morris & Oliver... 986,490
Vending machine coin operated mechanism, L. Horinko 986,985
Violin bow guide, L. G. Garrett 987,061
Vise, H. G. Miller 986,485
Vise attachment, A. D. Bach 986,619
Voting machine, I. R. Winslow...986,789, 986,790
Wagon box bracket, F. J. Fardon 986,913
Wagon, pump, R. Stuckwisch 986,604
Wagon, dumping, C. Lynch 986,582
Wagon seat, A. J. Wood 986,885
Washer. See Window washer.
Washing machine operating means, W. L. Cummer 986,805
Water closet, Miller & Hott 986,486
Water closet, J. Morrison 986,586
Water heater and purifier, J. E. Wood.... 986,886
Water purifier, Bowman & Wallace........ 986,897
Wave and current motor, J. T. Cross...... 986,802
Wave motor, ship's, H. E. Fisher 986,802
Wave power generator, R. M. Mobius..... 986,740
Wax finish, liquid, J. D. Bryant 987,042
Weather strip, J. Kammerer 986,828
Welding machine, electrical, E. E. McIntyre 986,845
Welding metal, W. M. Whitney 986,528
Wheel, C. Carpener 986,906
Wheel, V. O. Mervine 987,009
Whip holder, G. Kaiser 986,719
Whistle and fog horn, convertible, R. Berrenberg 987,038
Wicket trap, A. S. Harris 986,977
Window attachment, S. Weinstein 986,662
Window pane holder, H. Knoblauch........ 987,076
Window reacher, E. & F. Siegel 986,771
Window safety lock, F. Meszaros 986,737
Window washer, T. O'Brien 987,010
Wire fabric, woven, E. Hoffman 986,569
Wire rope or cable, T. Gore 986,817
Wrapping machine, Cowles & Hanford.... 986,548
Wrench, P. Roisum 986,593
Wrenches, wire holding means for, J. H. Sullivan 986,954
Wrist pad, W. R. Ballou 986,620
Yardstick, calculating, H. J. Weierhauser. 986,661
Yeast, manufacturing dry diastatic, P. A. Brangier 986,898
Yoke, animal, A. H. Thieme 987,025

A printed copy of the specification and drawing of any patent in the foregoing list, or any patent in print issued since October 4th, 1859, will be furnished from this office for 10 cents, provided the name and number of the patent desired and the date be given. Address Munn & Co., Inc., 361 Broadway, New York.

Canadian patents may now be obtained by the foregoing list. For terms and further particulars inventors for any of the inventions named in the address Munn & Co., 361 Broadway, New York.